CANADIAN JOURNAL
OF PLANT SCIENCE
(formerly published as part of "*Canadian Journal of Agricultural Science*")
VOLUME 37 OCTOBER, 1957 No. 4

METHODS OF EVALUATING STOCK/SCION COMPATIBILITY IN APPLE TREES[1]

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[Received for publication November 23, 1956]

ABSTRACT

Field and laboratory trials were carried out to test compatibility in two scion varieties grafted on eight lines of seedling crabapple rootstocks, and to compare several methods of evaluating stock/scion compatibility. Scion varieties were Rescue and Haralson; rootstocks were seedlings of Alberta, Beauty, Battleford, Columbia, Dolgo, Elsa, Osman and mixed seed of ornamental crabapples. Evaluation methods were per cent bud "take", water conductivity through unions, macroscopic and microscopic scoring of the unions, strength-at-union and type of union break under stress. No obvious cases of incompatibility were found. Under these conditions, no marked correlations could be established between any of the evaluation methods, nor did these methods yield similar results. One or more of the methods evaluated may be reliable, however, where a greater range in compatibility is being studied.

The need for proven evaluation measures for assessing rootstock and scion compatibility has long been recognized, and has been a subject of research during the past 50 years. Laboratory tests that would not entail growing the trees to fruiting age would greatly reduce the time required to assess stock/scion combining affinities.

Argles (2), after an extensive review of literature on the subject, suggested that the presence of isolated masses or sheets of parenchymatous tissue or bark at the line of union are symptomatic of inherent incompatibility and of no other disordered state. He also noted that other conditions which may be symptomatic of incompatibility but that possibly are due to other factors are: a relatively small proportion of successful unions formed; complete failure to form a union; premature decline and death of trees; ill health of trees and swelling at the union.

The presence of parenchyma at the line of union was recognized by a number of workers (3, 4, 7) to be a sign of incompatibility. Distortion of vascular tissues was also taken as a measure of incompatibility by Chang (3).

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The strength of the graft union as measured by the force required to break it has been claimed to reflect the degree of compatibility* (3, 10). Mosse and Herrero (6) take exception to this view and note that mechanically weak unions are not always associated with poor tree performance.

It is usually considered that enlarged unions and unions showing signs of bark discontinuity indicate incompatibility between stock and scion. Chang (3) stated that bark discontinuity was a symptom of incompatibility, but Hilton* found that crevices which appeared in the bark of compatible one- and two-year-old combinations disappeared later. Randhawa and Upshall (8) confirmed Hilton's observation, but claimed that swelling at the union is a normal expression of incompatibility.

Tydeman (11) and Amos *et al.* (1) accept graft or bud "take" as a measure of compatibility. Chang (3) concludes that it is not a reliable measure of compatibility, but Hilton observes that per cent "take" of plum scions of frameworked trees is a satisfactory indication of compatibility.

A positive correlation between compatibility and the amount of water which passes through a union under vacuum in a given time is reported by Chang (3), and Randhawa and Upshall (8). Conductivity of dyes through the union also gives a measure of compatibility (3).

Further compatibility evaluation measures include: (a) abnormal starch accumulation above the graft union (3, 6); (b) total elongation of scion (9, 11); and (c) early autumn foliage coloration (12).

MATERIALS AND METHODS

Seed of the following seven crabapple varieties was used for production of rootstocks: Alberta, Bedford, Columbia, Dolgo, Elsa, Osman, Beauty. In addition, rootstocks were grown from a seed mixture obtained from ornamental crabapple varieties. For convenience, this mixed lot, with part *Malus pumila* var. *Niedzwetzkyana* ancestry, is hereafter called "Ornamental". Thus there were eight rootstock lots in all.

The seed was sown after stratification, and the following year the seedlings were lined out in four rows. Each row was divided into four parts. A seedling line was assigned at random to each division of the two outside rows and to each division of the two inside rows. The division was made to compensate for environmental factors as true replication was not feasible.

In late July and early August, Rescue (an applecrab hybrid) and Haralson scion varieties were budded on the rootstock lines. Fifty buds of each variety were placed on each line at two different dates. Thus 100 Haralson and 100 Rescue were budded on each of the eight seedling lines. The outside rows were used at the first date and the inside rows at the second date. Lines for budding were selected at random.

The following June, tops were cut back to the buds, leaving a very short snag of the seedling stem above the bud. "Take" of buds was recorded in the early summer. In the late fall, the plants were observed for early defoliation or leaf coloration.

*Hilton, R. J. *Unpublished Doctoral thesis*, University of London. 1939.

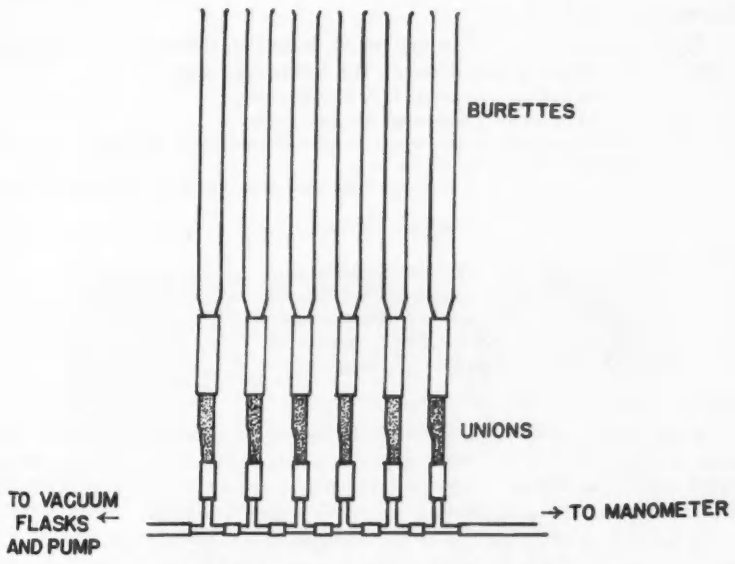

FIGURE 1. Water conductivity apparatus.

The plants were dug in October and, after the length of top growth was recorded, the top and roots were removed except for 6 centimetres above and below the union. Forty plants of each combination, chosen at random, were tagged with a number and the combination of stock and scion. The diameter of each of these plants was measured at 1 cm. above the union; 1 cm. below the union; 5 cm. above the union; and at the union. After measurement, the unions were stored in closed polyethylene bags with a moist sheet of paper towel at 36°F. until used for the various tests.

Water Conductivity Measurements

Apparatus adapted from that described by Chang (3) was assembled and is shown in Figure 1. The six combinations were inserted into the rubber tubes of the apparatus and then clamped. Cut surfaces, where roots and lateral branches had been removed, and the stub region were coated with a tenacious cheese-wax to exclude entrance of air at such places. The burettes were filled with water and the rubber tubes at their ends were pinched until all air was expelled. Suction was then applied and the mercury manometer maintained at 620 mm. The burettes were read 5 minutes and 15 minutes after suction was applied. The difference in the readings was taken as the amount of water passing through the union in 10 minutes.

The readings were converted to water conductivity per unit cross-sectional area of the scion at the union and at 5 cm. above the union.

Macroscopic Evaluation

Each union was scored from *1* to *10*, based on the external appearance of the union. Scoring was done on the following bases:

1. Severe swelling and severe bark discontinuity.
2. Moderate swelling and severe bark discontinuity.
3. Moderate swelling and moderate bark discontinuity, or slight swelling and severe bark discontinuity.
4. Slight swelling and moderate bark discontinuity, or no swelling and severe bark discontinuity.
5. Slight swelling and slight bark discontinuity, or no swelling and moderate bark discontinuity.
6. No swelling and slight bark discontinuity.
7. Severe swelling and no bark discontinuity.
8. Moderate swelling and no bark discontinuity.
9. Slight swelling and no bark discontinuity.
10. No swelling and no bark discontinuity.

Microscopic Evaluation

From each combination, one-half the total number of unions were taken at random for microscopic evaluation. The wax, which was retained after the water conductivity tests, was removed by dipping the unions in hot water and wiping them with paper towels.

A portion of the bud union region, approximately 2 centimetres long, was removed from each selected union, and the material thus prepared was placed for 48 hours in Farmer's Fixative, after being labelled to indicate the combination and number of the union. The unions then were placed in an alcohol-glycerol softening solution (50 per cent absolute alcohol—50 per cent glycerol), after softening transverse sectioning was attempted with a sliding microtome. Better sections were obtained when the unions were left in 95 per cent alcohol for 24 hours, and the microtome knife was cooled frequently and kept wet with glycerin and water.

The sections selected for examination were from the base of the scion in the region of the leaf scar. These were stained with Delafield's haematoxylin and Safranin [Johansen (5)], dehydrated, and mounted in Canada balsam. After drying for one month, they were scored on the following bases:

1. Stock and scion almost separate units, divided by cork cells or porous areas.
2. Stock and scion almost separate units, divided by cork and undifferentiated parenchyma.
3. Stock and scion almost separate units, divided by the parenchyma only.
4. Some union of wood but predominantly cork or parenchyma.
5. Parenchyma prominent, some cork.
6. Parenchyma prominent, or parenchyma and distorted xylem.
7. Isolated patches of parenchyma or cork, or mainly distorted xylem.
8. A little parenchyma in part of union or slight distortion of xylem; union otherwise good.
9. Wood tissue of stock and scion merge and line of union distinguishable only by presence of xylem from bud shield.
10. Line of union indistinguishable.

The sections were first examined under high power to identify the several tissues. After such identification, a dissecting microscope (15X) was satisfactory for evaluating the unions. Where the left and right

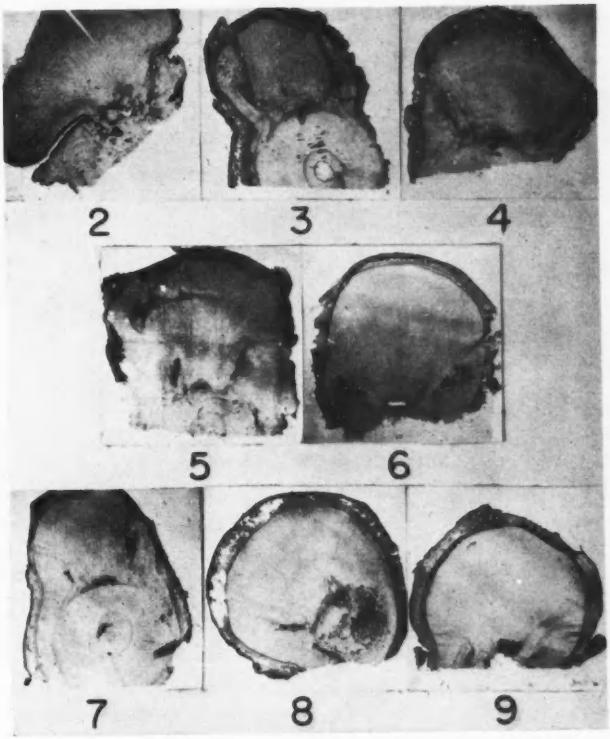

FIGURE 2. Sections of bud unions. The numeral beneath each section indicates the compatibility rating for that type of union.

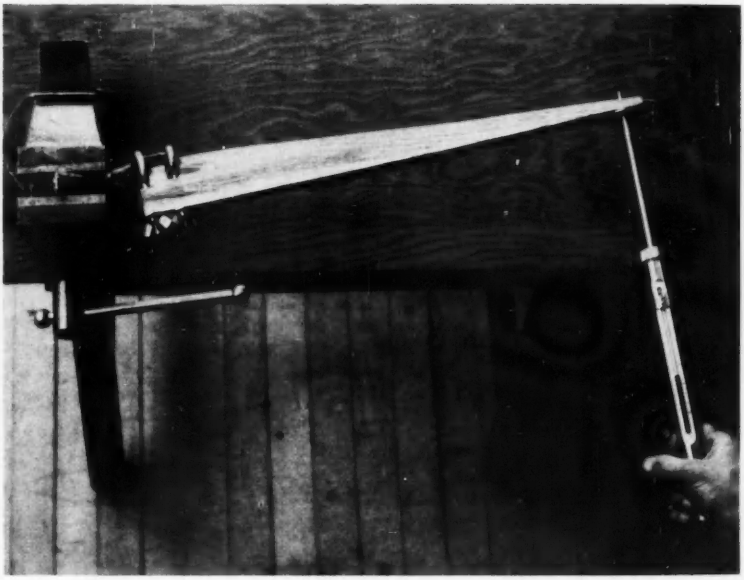

FIGURE 3. Breaking strength apparatus.

halves of any section differed, the two halves were evaluated and the mean recorded. Figure 2 illustrates the types of unions with score values from *2* to *9*.

Breaking Strength Tests

The remaining unions were broken, using the apparatus shown in Figure 3. This apparatus consists of: a vise in which the stock was fixed so that the budded side faced away from the operator; a hardwood arm approximately 55 cm. long, to which the scion was firmly fixed by ring bolts fitted with wing nuts; and a Ballauf Fruit Pressure Tester, which was used to exert a pressure on the wooden arm 50 cm. from the union. The formula for calculating the modulus of rupture (which is the fibre stress at the moment of breaking), recorded in pounds per square centimetre, was:

$$\frac{32 \times BM}{\pi d^3}$$, where BM = force applied × 50 cm., and d = diameter of union in cm.

As the unions were broken, a record was kept on whether the break was clean or jagged.

Analysing the Data

Correlation studies were made to determine whether or not relationships existed between the evaluation methods. In some cases, the coefficients were calculated for the whole population, but in others, for one or two combinations only. If no trend was observed when two or three combinations were used, that particular phase of the study was discontinued. In certain cases, partial correlation coefficients were calculated to remove the effect of stock diameter.

Analyses of variance were carried out on data for all tests. Analysis of covariance was applied to the scion diameter data to remove the effect of stock diameter.

Data on the type of break at the unions were compared with other data.

RESULTS AND DISCUSSION

Bud "Take"

Analysis of variance was applied to the "take" data. "Take" on rootstocks did not differ significantly, nor was the scion/rootstock interaction significant. There was a highly significant difference of "take" of scion varieties, but this is not considered relevant to the problem. Table 1 illustrates the "take" recorded.

TABLE 1.—MEAN PER CENT "TAKE" OF BUDS

Scion variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Beauty	Ornamental
Haralson	51	49	47	75	52	53	62	52
Rescue	88	89	84	82	91	92	94	90

Plant Maturity

No early or otherwise abnormal defoliation or foliage discoloration was observed in plants of any of the combinations under test.

Shoot Growth and Vigour

Extensive branching of the scion variety Rescue made it impossible to use shoot length as a quantitative measure. Correlation coefficients of scion diameter and shoot length (s) were calculated for 32 unbranched Haralson plants. The scion diameter at 1 cm. above the union (c) and scion diameter at 5 cm. above the union (i) were used. The coefficients of correlation were:

r_{sc}	.707	DF 30
r_{si}	.752	DF 30

Both values are highly significant.

The higher correlation with the scion diameter at 5 cm. is attributed to swelling from the union, which in many cases affects the diameter at 1 cm.

The regression equation calculated for shoot length on scion diameter at 5 cm. was:

$$S = 40.9 + 71.28\,i$$

When i for certain branched Haralson plants was substituted in the equation, no fixed proportion of the lateral growth could be applied to the central growth to produce the same value as the regression equation. However, in no case was the lateral growth less than that necessary to bring the measurement up to the calculated value.

TABLE 2.—MEAN SCION DIAMETERS IN CENTIMETRES ADJUSTED FOR VARIATION IN ROOTSTOCK DIAMETER

Scion variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Beauty	Ornamental
Haralson	0.88	1.00	0.90	0.95	0.97	0.99	0.99	0.94
Rescue	0.96	1.07	1.06	1.05	1.06	1.07	1.14	1.07

L.S.D. (0.05) = 0.09 cm.

TABLE 3.—CORRELATION COEFFICIENTS FOR WATER CONDUCTIVITY AND OTHER METHODS OF EVALUATION

Correlation between	Coefficient
Conductivity (w) and modulus of rupture	+0.196**
Conductivity (v) and modulus of rupture	+0.293**
Conductivity (w) and scion diameter	+0.074
Conductivity (v) and scion diameter	+0.263**

DF = 318

**Significant at 1% level.

The observed correlation of shoot length and diameter is considered large enough to warrant the use of diameter as a measure of vigour, especially when 20 or more values are used for each combination.

It was realized that stock diameter (d) doubtless would influence the scion diameter. The correlation of these factors for two combinations were:

r_{di}	0.686	DF 18
r_{di}	0.758	DF 18

Both coefficients are highly significant.

Scion diameter data were adjusted for variation in stock diameters by using analysis of covariance. The scion/rootstock interaction was still significant after adjustment.

Table 2 provides data on adjusted scion diameters and shows that with the scion variety Haralson, when Columbia is used as a standard, no rootstock is inferior to Columbia, while Bedford, and possibly Osman and Beauty, are superior. With the scion variety Rescue, no rootstock is superior to Columbia, and Alberta is inferior.

Water Conductivity Tests

Water conductivity was calculated using the scion diameter at 5 cm. above the union, and the mean diameter measured 1 cm. above and below the union. These values are referred to as w and v, respectively. Correlation coefficients for water conductivity (calculated by each method) and breaking strength, and scion diameter, are reported in Table 3. The increase in correlation when union diameter is used to calculate water

TABLE 4.—MEAN WATER CONDUCTIVITY IN ML. PER 10-MINUTE INTERVAL PER SQ. CM. CROSS-SECTION OF UNION

Rootstock							
Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Beauty	Ornamental
2.5	3.3	4.0	2.6	3.1	2.9	3.1	2.3

L.S.D. (0.05) = 1.0 ml.

TABLE 5.—CORRELATION COEFFICIENTS FOR MACROSCOPIC AND OTHER METHODS OF EVALUATING UNIONS

	Method			
	Breaking strength	Water conductivity	Scion diameter	Microscopic evaluation
Coefficient	+0.279	+0.530*	+0.492**	+0.362
DF	18	18	158	18

**Significant at 1% level.
*Significant at 5% level.

conductivity indicates that scion diameter is not the limiting factor, and that union diameter, rather than scion diameter, should be used in calculating water conductivity. The low correlation between water conductivity and the other methods, while significant, precludes the use of the water conductivity method as a measure of the other two methods.

Analysis of variance of the water-conductivity data showed a significant rootstock difference. Table 4 shows that Alberta, Dolgo, Osman and Ornamental are inferior to Columbia, while no rootstock is superior.

Macroscopic Evaluation

Correlation coefficients for macroscopic evaluation and other methods of evaluation are shown in Table 5.

The degree of association between macroscopic evaluation and other methods is low, although with scion diameter and water conductivity the correlation is noteworthy. The association between macroscopic evaluation and scion diameter should, however, be viewed with suspicion, because the evaluator may be influenced by size of union when evaluating the union macroscopically.

TABLE 6.—MEAN SCORE UNITS FOR MACROSCOPIC EVALUATION OF UNIONS

Scion variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Beauty	Ornamental
Haralson	7.5	7.5	7.7	7.5	7.8	7.8	7.4	7.1
Rescue	7.7	7.9	7.9	7.4	7.9	7.8	8.5	8.1

L.S.D. (0.05) = 0.6 score units.

TABLE 7.—MEAN SCORE UNITS FOR MICROSCOPIC EVALUATION OF UNIONS

Scion variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Beauty	Ornamental
Haralson	6.9	7.2	5.5	5.9	5.9	6.5	6.6	6.3
Rescue	6.5	7.0	6.5	5.3	7.1	6.3	7.4	7.3

L.S.D. (0.05) = 0.8 score units

TABLE 8.—CORRELATION AND PARTIAL CORRELATION COEFFICIENTS FOR SCION DIAMETER AND MODULUS OF RUPTURE

Combination	With stock diameter influence	Stock diameter influence removed
Haralson on Alberta	+0.469*	+0.532*
Rescue on Alberta	+0.518*	+0.565**
Rescue on Beauty	+0.300	+0.401
Rescue on Elsa	−0.169	−0.083

DF = 18

** and * = Significant at levels of 1% and 5% respectively.

Analysis of variance was applied to the macroscopic evaluation data. A significant scion/rootstock interaction was evident. The arithmetic means of macroscopic evaluation scores in Table 6 show that within each scion variety no rootstocks are superior or inferior to Columbia; although with Rescue, Beauty is possibly superior, and with Haralson, Ornamental is possibly inferior.

Microscopic Evaluation

Typical correlation coefficients for microscopic evaluation and water conductivity, and microscopic evaluation and scion diameter, were 0.342 and 0.013, respectively. Neither of these values was significant. Unions that were sectioned could not be broken, and hence this relationship was not studied. The low correlation of microscopic evaluation with macroscopic evaluation may be noted in Table 5. If any of the other methods of evaluation investigated here are assumed to be reliable standards, microscopic evaluation does not appear to be a good measure of compatibility.

Analysis of variance showed that the scion/rootstock interaction was highly significant. It can be seen from Table 7 that with the scion variety Haralson and using Columbia as a standard, when the L.S.D. is applied, the rootstocks Alberta, Bedford, Osman, Beauty and possibly Ornamental, are superior to Columbia. With the scion variety Rescue, Beauty and possibly Ornamental are superior, while Dolgo is inferior.

Breaking Strength Tests

Correlation coefficients for modulus of rupture and scion diameter at 5 cm. were calculated. Partial coefficients were also calculated for a few combinations to study the effect of stock diameter. The increase in positive correlation with removal of stock diameter influence is evident in all four combinations reported in Table 8. The over-all low association of the two methods being discussed makes the acceptance of either method as a measure of the other impossible.

The analysis of variance of breaking-strength data indicates a highly significant scion/rootstock interaction. Table 9 shows that with the scion variety Rescue, Bedford is the only rootstock producing a significantly stronger union than Columbia. There are no other significant differences.

Type of Break

The type of break—that is, whether the break was clean or jagged—did not reveal any trend. It is unlikely that this method of evaluation has any merit for comparison of unions which do not differ appreciably from one another in their compatibility.

TABLE 9.—MEAN MODULUS OF RUPTURE IN LB. PER SQ. CM.

Scion variety	Rootstock							
	Alberta	Bedford	Columbia	Dolgo	Elsa	Osman	Beauty	Ornamental
Haralson	368	365	297	371	367	350	342	266
Rescue	312	428	351	392	348	343	413	413

L.S.D. (0.05) = 76 lb.

CONCLUSIONS

The methods investigated for their value in assessing scion/rootstock combinations do not yield similar results, nor do they appear to be correlated to any marked extent. Most of the methods studied have been accepted by some workers, as was outlined in the literature review. All of these workers used combinations of known compatibility, and hence were able to evaluate their methods on this basis.

In this study, the lack of combinations of known compatibility, and especially of those known to be incompatible, has been a serious handicap. It is likely that the unions used here are highly compatible. The differences observed may be due to factors other than compatibility, and these differences are so slight that if high degrees of incompatibility were present such minor differences may have been masked.

The correlation between the methods may also be affected by factors other than compatibility. Where the range of compatibility is narrow, slight differences due to many other factors may make the apparent correlation much less than the true correlation. Included among such factors might be soil heterogeneity and heritable differences in the wood of the rootstocks. The results obtained in this investigation should not be taken to mean that one or more of the methods are not reliable measures where a greater range in compatibility is being studied.

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THE IDENTIFICATION AND DISTRIBUTION OF PHYSIOLOGIG RACES OF *ASCOCHYTA PISI* LIB. IN CANADA[1]

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[Received for publication November 9, 1956]

ABSTRACT

Based upon the reactions of seven pea varieties selected for their suitability as differential hosts, four distinct physiologic races of *Ascochyta pisi* Lib. were found among 80 isolates of the fungus obtained from diseased pea plants and infected seeds from six provinces in Canada. The geographic distribution of each of the races was as follows: I and II from the Prairie Provinces; III the Georgian Bay area and central Ontario, and IV the Ottawa Valley and to a lesser extent central and western Ontario, Quebec, and Nova Scotia.

INTRODUCTION

Of the diseases of peas that are transmitted by infected seed, the leaf and pod spot caused by the fungus *Ascochyta pisi* Lib. is one of the most serious and prevalent. In the United States it is surpassed in importance by the diseases caused by the closely related fungi *Mycosphaerella pinodes* (Berk. & Blox.) Vestergr. and *Ascochyta pinodella* L. K. Jones (3), but judging from the relative frequency with which each organism has been isolated from pea seed from various parts of Canada by the Botany and Plant Pathology Laboratory at Ottawa, Ont., a higher percentage of Canadian produced seed is infected with *A. pisi* than with either of the other two organisms (4).

In the leaf and pod spot disease, the fungus frequently produces deep-seated infection within the seed. There is little evidence that any seed treatment other than hot water will disinfect such seed. This has not been used to any extent because of the impracticability of such treatment and the danger of impaired germination of the seed. It is therefore necessary to recommend the use of disease-free seed as the only practical means of control.

In the United States the decline in importance of leaf and pod spot in recent years has been attributed to the use of disease-free seed produced in the semi-arid western states. Despite the use of such seed, periodic outbreaks of the disease have occurred, particularly in the east where humid conditions are favourable for its development. This is not surprising since it is well known that the pathogen may overwinter on debris in the field (5, 2). Observations made at this laboratory show that the capability of certain species of vetch to act as hosts contributes to the difficulty of controlling this fungus.

During the past five years, 250 varieties and selections of peas have been tested for resistance to *A. pisi*. None was found to be immune, and extreme variability in varietal susceptibility has occurred from year to year. For these tests, a spore suspension of single isolates from most

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areas where *Ascochyta pisi* had been found was used. The differences in pathogenicity exhibited by the various isolates of *A. pisi* to these varieties was soon recognized as evidence of physiologic specialization. It became obvious, therefore, that the determination of the number of physiologic races, their prevalence and distribution in Canada, was prerequisite to a program of testing for resistance and the breeding of resistant varieties.

The existence of physiologic races was indicated by the work of Jones (3). He reported that "a marked difference in susceptibility of certain varieties to attack by different isolates of *A. pisi* was noted". Bondartzeva-Monteverde and Vassilievsky (1) reported the existence of five races of *A. pisi* in Russia. Gilpatrick and Busch (2) distinguished at least three physiologic races based upon the pathogenicity of seven isolates of *A. pisi* on eight varieties of peas and three species of vetch.

MATERIALS AND METHODS

Since 1949, 174 isolates of *Ascochyta pisi* have been obtained from various localities throughout Canada. Staff members of various laboratories of the Botany and Plant Pathology Division and the Ontario Agricultural College co-operated by sending diseased material from which the various isolates were obtained. Other isolates were secured from material collected during annual field surveys of pea fields of Canners Seeds Limited, from inspections of foundation field and garden peas at experimental stations throughout Canada, and from pea seed samples sent in to be examined for foundation status.

Since their isolation the cultures have been grown on 2 per cent pea agar in test-tubes. Some have died and others have ceased to develop pycnidia. All were kept at room temperature throughout the inoculation trials, except for a short period when some transfers were held in a refrigerator; however, it was found that cool conditions favoured the development of mycelium rather than pycnidia. Transfers have been made monthly and at time of writing some of the isolates are still as pathogenic as when they were isolated as early as 1949.

Of the 80 isolates chosen for this work, 37 were isolated from diseased material collected in the Ottawa Valley, mainly from the Central Experimental Farm at Ottawa, 10 from central Ontario, and 13 from the Georgian Bay district and western Ontario. In addition, 13 isolations were made from diseased pea crops in various parts of Manitoba, 3 from Alberta, 2 from Quebec, and 1 each from Saskatchewan and Nova Scotia.

In order to ensure purity of the isolates, each culture was monospored. In preliminary trials it was evident that the method of inoculation and the conditions of incubation markedly influenced the degree of infection and that standardization of these conditions was essential for uniformity of results. The method finally adopted was to use a 7-day-old culture of *A. pisi* from which a spore suspension in 5 ml. sterile water was prepared. Fourteen-day-old pea seedlings, grown in 7-inch pots, 10 seeds per pot, were prepared for inoculation by rubbing the leaves and stems very lightly with sandpaper of extra fine grade. A spore suspension of *A. pisi* was

sprayed on to the plants by means of a deVilbiss atomizer, No. 287, which delivered approximately 5 ml. of the suspension to each pot. The inoculated plants were then removed to a constant temperature incubator set to hold a temperature of 18°C. and a high relative humidity. After 24 hours' incubation the plants were placed in a greenhouse with similar conditions of temperature and relative humidity. After 14 days in the greenhouse the plants were examined for symptoms of infection.

As the leaves and stems of some varieties were not equally susceptible to the isolates, a scale of reaction ratings involving five distinct degrees of response was made for each. After over 50 varieties were screened for their use as differentials in the recognition of physiologic races within the 80 isolates tested, the following were selected: Wisconsin Early Sweet, Arthur, Engress, Profusion, Kelvedon Wonder, Smallton, and Valley. The letters *A* to *E* were used to indicate the reaction on the leaves and the numbers *1* to *5* for the stems. The reaction ratings and descriptions are given in the following tabular form:

Degree of resistance	Reaction designation		Description of reaction
	Leaves	Stems	
Highly resistant	A	1	Small flecks only
Moderately resistant	B	2	Small lesions, no pycnidia
Moderately susceptible	C	3	Necrotic lesions, pycnidia present
Very susceptible	D	4	Deep necrotic lesions, abundant pycnidia
Highly susceptible	E	5	Plants killed

During the past four years, the majority of the isolates have been tested on the seven differentials from three to six times with consistently uniform results. Based upon isolates which have been tested at least three times, results show at least four races of *A. pisi* were present.

Table 1 shows the reaction according to the above scale of the various differential varieties to the four races of *Ascochyta pisi*. In this table it

TABLE 1.—REACTION OF DIFFERENTIAL VARIETIES OF PEAS TO RACES OF *A. pisi*

Variety	Race			
	I	II	III	IV
W. E. Sweet	B2	B2+	C3+	C3+
Arthur	B2	B2	C3	C2+
Engress	C2	C3	C2+	C3
Profusion	B2	B2	B+2+	B+2+
Kelvedon Wonder	B1+	B2	D4	B2
Smallton	B+2+	C+3−	D4	C+3+
Valley	B+2+	C+3−	D4	C+3+

+ A slightly more positive reaction than the number or letter indicated.

TABLE 2.—DISTRIBUTION OF PHYSIOLOGIC RACES OF *Ascochyta pisi* IN SIX PROVINCES OF CANADA

Province	Number of collections of race:			
	I	II	III	IV
Nova Scotia	0	0	0	1
Quebec	0	0	0	2
Eastern Ontario	3	0	0	34
Central Ontario	0	0	9	1
Western Ontario	0	1	7	5
Manitoba	9	4	0	0
Saskatchewan	1	0	0	0
Alberta	1	2	0	0
Total	14	7	16	43

can be seen that races I and II were quite similar except that the varieties W.E. Sweet, Engress, Smallton, and Valley were more susceptible to race II. A number of the varieties were more susceptible to race III including Kelvedon Wonder, which was resistant to all other races. Race IV attacked all varieties except Kelvedon Wonder.

The occurrence and geographical distribution of these races was noteworthy. In Table 2 it is seen that of the 14 isolates designated as race I, 9 were from Manitoba, 3 from eastern Ontario and 1 each from Saskatchewan and Alberta. Race II comprised 6 isolates from Manitoba, and 1 each from Alberta and western Ontario. Races I and II were weakly pathogenic and it may have been possible that the 3 isolates from Eastern Ontario, all of which were maintained since 1949, were simply weakly pathogenic isolates. All other isolates from eastern Ontario were of race IV. Race III consisted of 16 isolates and all were located in central and western Ontario. Representatives of this form were extremely pathogenic and were the only isolates which severely attacked the variety Kelvedon Wonder. Race IV, which comprised 43 isolates, was predominantly from eastern Ontario, although representatives of this form were located in western and central Ontario, Nova Scotia and Quebec.

DISCUSSION OF RESULTS

Evidence is presented that at least four physiologic races of *Ascochyta pisi* exist in Canada. An interesting observation is that each race has a geographically limited distribution. With minor exceptions, races I and II are present in the western provinces, race III is present in central and western Ontario, and race IV in eastern Canada. The fact that these races may be geographically located is difficult to understand in view of the seed-borne nature of the disease and the transport of infected seed

throughout the country. However, it is possible that climatic conditions may favour the development of one race over another in any one section of the country.

As only one physiologic race appears to predominate in a given area in Canada the selection of resistant varieties for use in the different pea-growing areas might be a relatively simple matter. However, it should be stressed that the method used here to distinguish physiologic races may not necessarily be a valid means of indicating susceptibility or resistance of a variety under field conditions.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Angela Wallace for technical assistance, and to L. H. Lyall and J. G. C. Fraser for supplying the pea seed for these investigations.

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ROOT AND STALK ROT OF FIELD CORN IN SOUTH-WESTERN ONTARIO

I. SEQUENCE OF INFECTION AND INCIDENCE OF THE DISEASE IN RELATION TO MATURATION OF INBRED LINES[1]

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[Received for publication December 26, 1956]

ABSTRACT

Examination of selected corn inbreds in a disease nursery revealed that root rot and stalk rot are successive phases of a disease which begins in the roots and later spreads into the stalk. Stalk rot first appeared on the inbred of early maturity, later on the inbred of medium maturity, and still later on the inbreds of late maturity. The stalk rot phase of the disease did not occur until the inbreds had reached a late stage in their development.

INTRODUCTION

Root and stalk rot of field corn in southwestern Ontario was first reported by McKeen (2) in 1949. Since then the disease has increased yearly throughout this region, the highest incidence being in seasons when corn matures early. The stalks of severely diseased plants usually collapse at the first or second internode above ground and break over in characteristic fashion (Figure 1). It has been observed that stalk rot appears late in the growing season and that early maturing hybrids and inbreds are usually the first to show disease symptoms. As the name root and stalk rot suggests, both the roots and stalks of diseased plants are affected (Figure 2). Although McKeen (3) reported that the disease usually begins in the roots and spreads into the stalks he showed few data in support of his conclusion. This paper presents data on the relationship between root rot and stalk rot, and the incidence of disease in relation to the maturity of four inbred lines of corn and to the age of the host.

MATERIALS AND METHODS

The present studies were conducted in 1954 and 1955 in a disease nursery at the Experimental Farm, Harrow, Ontario. Four inbred lines of dent corn were selected to represent three maturity groups: *early*—M13; *medium*—CH39; *late*—WF9 and HY. Each inbred was planted on six different dates at approximately 10-day intervals, beginning May 12, 1954, and May 9, 1955. A split-plot design with three replications was used with planting dates as sub-plots. Each plot consisted of a 20-foot row of individual plants, one foot apart. Data on the occurrence of stalk rot were recorded at weekly intervals, starting at the time of its first appearance and continuing until the corn was harvested. Stalks were considered diseased if they collapsed at the first or second internode above ground when pressure was applied by the thumb and index finger. The plants were dug at harvest and severity of root rot assessed on the basis of a

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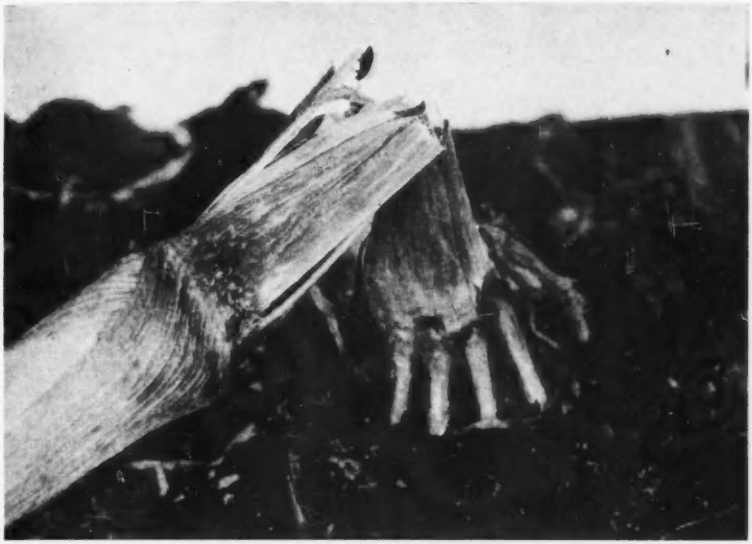

FIGURE 1. A typically collapsed, diseased plant.

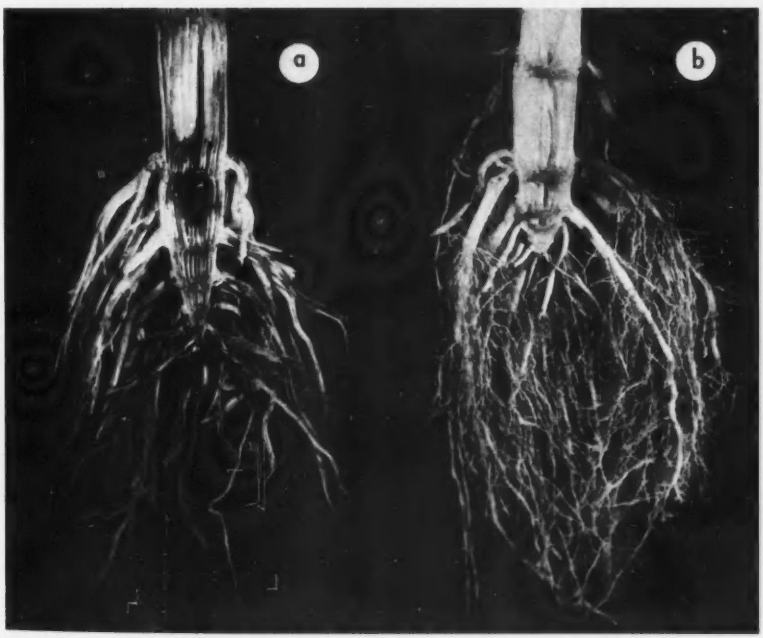

FIGURE 2. Roots and lower stalk tissue of a diseased plant (*a*), and a healthy plant (*b*).

disease rating of 0 to 4 as follows: 0—*no disease*; 1—*disease restricted to the tips of the roots*; 2—*disease restricted to the lower half of the roots*; 3—*some of the roots totally diseased, the remainder only partly diseased*; 4—*all of the roots totally diseased*. As all plants with rotted stalks were identified, it was possible to relate the condition of the root with the presence or absence of stalk rot. Root and stalk tissues from diseased and healthy plants were examined for the presence of possible pathogens and isolations were made to determine their identity.

All of the seed in these experiments was treated with Semesan Jr.

EXPERIMENTAL RESULTS AND CONCLUSIONS

Relationship between Root Rot and Stalk Rot

A total of 4676 plants was examined during the investigation. Only 1727 (36.9 per cent) had stalk rot, but all of these had root disease ratings of either 3 or 4. Of the remaining 2949 plants which showed no evidence of stalk rot, 579 (19.6 per cent) had root disease ratings of 3 or 4 while 2370 (80.4 per cent) had ratings of 0 to 2. The fact that the occurrence of stalk rot was always associated with a root disease rating of 3 or 4, and never with a rating of 2 or less, provides very strong circumstantial evidence of an inseparable relation between infection of the root and that of the stalk.

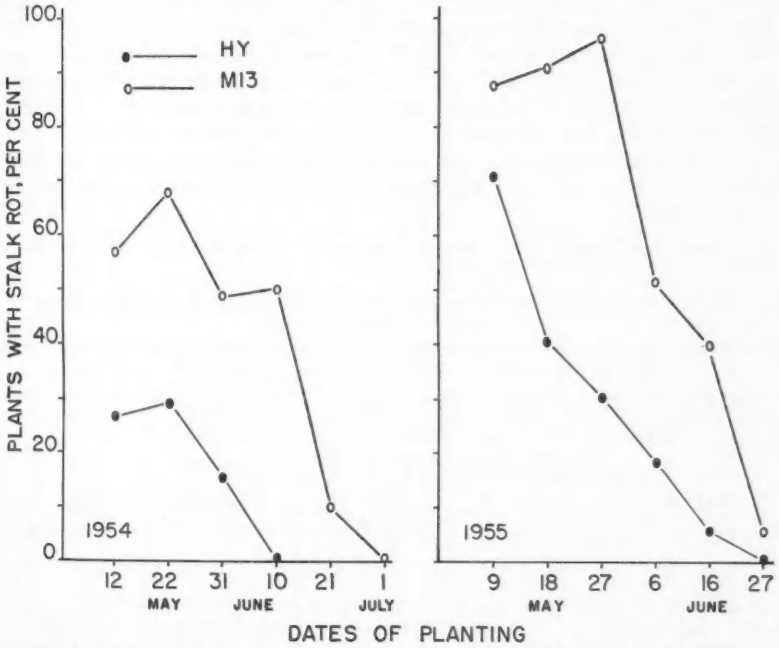

FIGURE 3. Percentage of plants with stalk rot in inbreds HY and M13 in each of six plantings in 1954 and in 1955. Examinations were made at harvest, November 7, 1954, and October 18, 1955.

Detailed examination of the lower nodal and crown region of many plants revealed that the disease, which first affected the adventitious roots, spread upward through the roots into the stalks. Isolations from roots, nodes, and internodes of diseased plants revealed that the same spp. of fungi predominated in all three regions*.

The preceding evidence indicates that root rot and stalk rot of corn in southwestern Ontario are two phases of the same disease in which infection begins in the roots and spreads from there into the stalks.

Incidence of Disease in Relation to the Maturity of the Host

The percentage of plants with stalk rot in each of the six plantings of the early inbred M13 and of the late inbred HY at harvest in 1954 and 1955 is shown in Figure 3. The early inbred M13 had a higher percentage of plants with stalk rot than the late inbred HY at all planting dates in both years.

Although not depicted in Figure 3 the incidence of stalk rot in the late inbred WF9 closely approximated that in HY. Incidence of the disease in the medium inbred CH39 was median between that of the early and late maturing inbreds.

Stalk rot was first observed on the early inbred M13 on August 30, on the medium inbred CH39 on September 6, and on the two late inbreds WF9 and HY on September 20 (Figure 4). The percentage of plants with stalk rot increased at approximately the same rate in the early inbred M13 and the medium inbred CH39. A slightly faster rate was indicated for the two late inbreds WF9 and HY. Although stalk rot first appeared in the late inbreds three weeks after its appearance in M13, all inbred lines eventually had approximately the same amount of stalk rot.

The results show that the maturity of corn has an effect on stalk infection in that corn of early maturity becomes diseased before corn of later maturity.

*Two species of *Fusarium* and one species of *Pythium* were isolated consistently from these regions. The pathogenicity of these fungi is under study.

TABLE 1.—DATE OF FIRST APPEARANCE OF STALK ROT IN FOUR CORN INBREDS PLANTED ON SIX DATES, 1955[1]

Date planted	Inbred			
	M13	CH39	WF9	HY
May 9	Aug. 30	Sept. 6	Sept. 20	Sept. 20
May 18	Sept. 6	Sept. 13	Sept. 20	Sept. 29
May 27	Sept. 6	Sept. 20	Oct. 6	Oct. 6
June 6	Sept. 13	Sept. 29	Oct. 18	Oct. 18
June 16	Sept. 29	Oct. 6	—[2]	Oct. 18
June 27	Oct. 18	—[2]	—[2]	—[2]

[1]Examinations made at weekly intervals beginning August 16.
[2]No stalk rot evident at time of harvest, October 18.

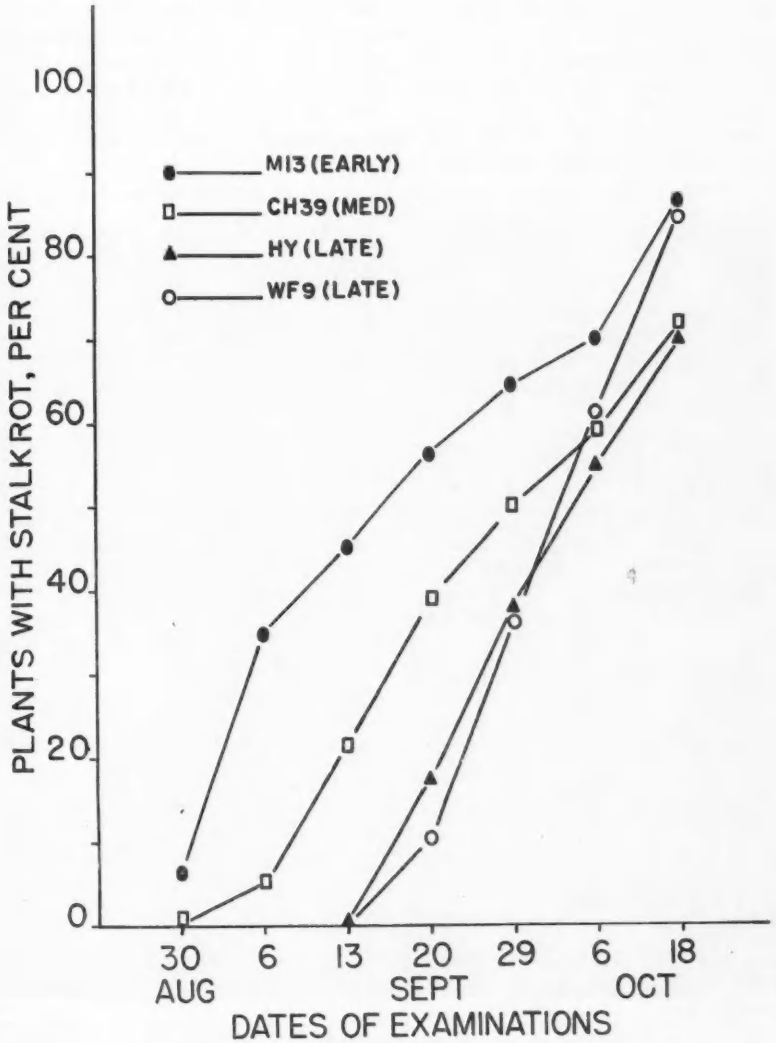

FIGURE 4. Percentage of plants with stalk rot at seven examination dates in each of four inbreds planted on May 9, 1955.

Incidence of Disease in Relation to the Age of the Host

The initial appearance of stalk rot in the four inbreds studied was closely associated with plant age (Table 1; Figure 5). Since similar results were obtained in both years, only the data for 1955 are presented. In all cases stalk rot appeared first on the earliest planting of each inbred, and as the planting was delayed the appearance of stalk rot was correspondingly

delayed. In the few instances where stalk rot first appeared on the same date in more than one planting of an inbred, the earlier planting always had a higher percentage of diseased plants than the later planting. This would indicate that the disease had occurred in the earlier planting a few days before it did in the later planting. The exact date of the initial appearance of stalk rot was not always recorded because examinations were made at weekly intervals.

From these results it is evident that the host must be in a late stage of its development before the disease occurs in the stalk.

DISCUSSION

Previous workers, McKeen (3) and Hooker (1), found an association between stalk rot and root necrosis in corn. The present investigation confirms this association and presents information on the time and place of infection. In these studies it was found that stalk rot occurred after the pathogens had spread from the roots into the stalk and did not develop unless the root system was nearly totally diseased. Hooker (1) stated that "the high association between basal stalk rot resistance and low degrees of root necrosis suggests that a reasonable rating for root necrosis can be inferred from a stalk rot evaluation". The present investigations show, however, that it is possible for plants to have totally diseased roots but no evidence of stalk rot, and that plants with rotted stalks always had badly diseased root systems. This suggests that more accurate classifications for stalk rot resistance are possible by root necrosis ratings than are root necrosis ratings by stalk rot evaluations. Preliminary experiments on resistance have indicated that resistance to this disease is in the roots and when the disease does not develop on the roots the stalks remain healthy. Thus it may be that the expression "stalk rot resistance" is a misnomer for resistance to the disease under study.

In the opinion of the authors it is not sufficient to evaluate resistance of corn plants to root and stalk rot on the examination of the stalks alone unless such an evaluation is made after the plants have matured so that those plants which have temporarily escaped will not be classified as resistant.

ACKNOWLEDGEMENT

The authors wish to express appreciation to L. W. Koch, H. F. Murwin and A. A. Hildebrand, for helpful suggestions in the preparation of the manuscript.

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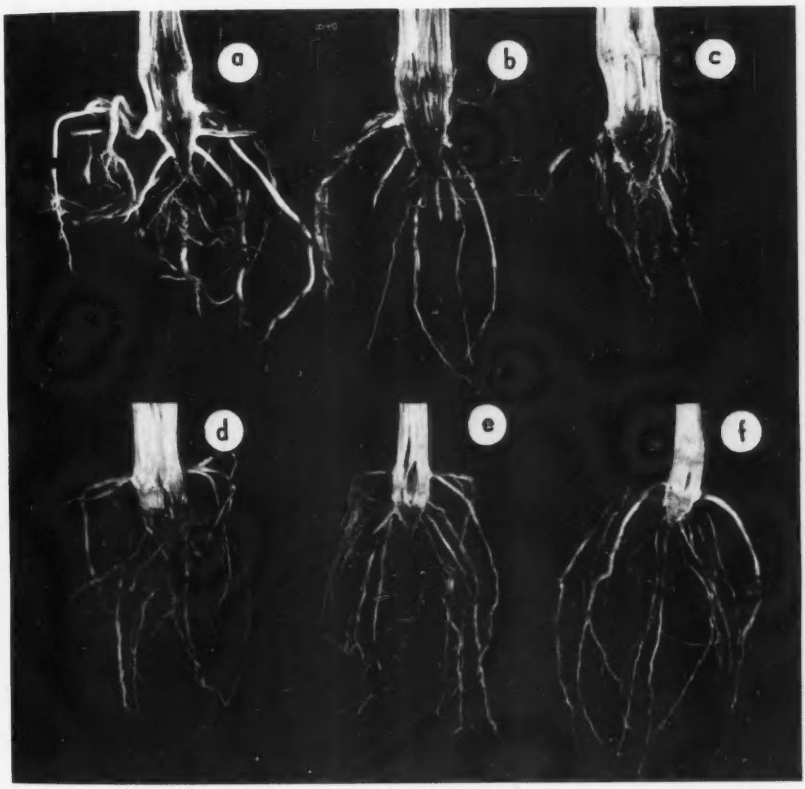

FIGURE 5. Severity of disease on inbred CH39 in relation to planting date. Plants *a*, *b*, *c*, *d*, *e*, and *f* were selected from populations planted May 9, 18, 27 and June 6, 16 and 27, respectively.

FURTHER STUDIES OF THE RELATIONSHIP OF SOIL PHOSPHORUS TESTS TO THE PHOSPHATIC FERTILIZER REQUIREMENT OF THE TOMATO[1]

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[Received for publication January 4, 1957

ABSTRACT

From previous results and from 16 additional trials relating Bray acid-soluble plus adsorbed phosphorus to the phosphorus fertilizer requirement of the tomato crop in Prince Edward County, Ontario, the mean c_1 constant for 66 trials was 0.00410, and the mean c constant for 40 comparisons was 0.00428. The standard error was ± 0.00027 for the mean c_1 value and ± 0.00031 for the mean c value. The mean c_1 value for trials conducted in a single year differed from the mean for all trials in only one of six years. The mean c value for each of three years did not deviate significantly from the general mean.

The use of the established constants in estimating the amounts of phosphorus required for 95 per cent of maximum yield in the area is illustrated for a range of soil test values. When recommended amounts of phosphorus for 95 per cent of maximum yield were used in the 16 trials, the mean value obtained for percentage of maximum yield was 96. With less than the recommended amounts, the values for percentage yield tended to decrease, the mean value for three-quarters of that recommended being 89 per cent.

INTRODUCTION

Since 1950, fertilizer experiments have been conducted on different farms in Prince Edward County, Ontario, to establish a basis for the satisfactory use of soil tests for estimating the fertilizer phosphorus requirement of the tomato crop. The approach followed has been that described by Bray (1), who used a modified interpretation of Mitscherlich's Law of Diminishing Returns. The relationship between soil test value and fertilizer requirement is expressed as follows:

$$\text{Log (A-y)} = \text{Log A} - (c_1 b_1 + cx)$$

where A, the yield for adequate amounts of nutrients, is 100 per cent; y, the yield for adequate amounts except phosphorus, is expressed as a per cent of A; b_1 is the phosphorus soil test value in lb. P per acre; x is the increment of phosphorus fertilizer added in lb. P_2O_5 per acre; and c_1 and c are proportionality constants. The c_1 constant relates the soil test value to the percentage sufficiency of soil phosphorus, whereas the c constant permits estimation of the fertilizer requirement from the soil test value. The estimation may be the fertilizer requirement for maximum yield or for any desired percentage of the maximum yield.

A c_1 constant derived from the results of four years' trials, and a c constant based on trials conducted in one year only, were reported previously (2). The purpose of the present paper is to report on further trials conducted in 1954 and 1955, to summarize the results to date, and to illustrate the use of the constants in estimating the fertilizer requirements for a range of soil test values.

[1]Joint Contribution from the Horticulture Division, Experimental Farms Service, and the Chemistry Division, Science Service. Scientific Contribution No. 875, Horticulture Division and Contribution No. 340, Chemistry Division.

TABLE 1.—SOIL TEST VALUES AND YIELD DATA FOR TOMATO TRIALS CONDUCTED IN 1954 AND 1955

Trial	Soil test	Yield for adequate P	Recom'd rate of P*	Percentage yield for less than adequate rate of P**				
				Recommended	¾ recommended	½ recommended	None	L.S.D. (P.05)
	lb. P/ac.	tons/ac.	lb. P_2O_5/ac.					
1954								
1	95	17.8	222	98	85	86	53	8.9
2	178	9.2	108	95	87	85	53	4.6
3	101	11.4	222	102	94	88	65	4.5
4	272	16.2	85	94	89	92	89	N.S.
5	192	13.5	160	99	92	94	74	12.2
6	227	7.1	67	94	91	92	75	3.8
7	145	7.7	92	90	87	86	70	N.S.
1955								
8	131	13.3	181	90	—	—	70	13.5
9	72	14.0	231	93	—	—	69	17.3
10	136	24.1	151	95	—	—	85	4.8
11	171	25.0	146	98	—	—	94	10.8
12	225	9.4	205	102	—	—	91	4.9
13	96	20.7	250	92	—	—	45	10.1
14	196	17.4	181	94	—	—	70	5.5
15	179	20.3	151	98	—	—	84	8.4
16	248	19.4	146	101	—	—	84	5.8
Average	167	15.4	162	96			73	

* Amount required for 95% of yield expected with adequate rate of P; based on fall soil samples.
** Yields are expressed as percentage of those for adequate P (360 lb. P_2O_5 per acre).

MATERIALS AND METHODS

Fields varying in fertility levels were selected on growers' properties on most of the soil types on which tomatoes are grown in Prince Edward County. The soils, described by Richards and Morwick (4), tend to be neutral or somewhat alkaline in reaction although some are moderately acid. There were seven trials in 1954 and nine in 1955. Two of the treatments included in all trials were as follows: (i) Nitrogen and potassium at the rate of 60 lb. N and 300 lb. K_2O per acre to supply adequate quantities of these nutrients; (ii) Same as (i) plus phosphorus at the rate of 360 lb. P_2O_5 per acre to supply an adequate quantity of this nutrient. Other treatments, similar to (ii) except with intermediate levels of phosphorus, varied in the different trials in accordance with estimated phosphorus requirement. The amounts of phosphorus recommended for 95 per cent of the production expected with the adequate rate were computed from soil test values, the mean c value established in 1953, and the mean c_1 value for the period 1950–1953 inclusive. These recommended amounts of phosphorus as well as three-quarters and one-half of such amounts were employed as intermediate rates in 1954. In 1955, the recommended rate of phosphorus was based on the mean c value for 1953–1954, and was the only intermediate level employed. The treatments were replicated three times. The soil test values represented the amounts of acid-soluble plus adsorbed phosphorus as determined by the method of Bray (1). For computing the constants, the values were based on soil samples taken before fertilizers were applied in the spring. The soil test values used in estimating the recommended rates of phosphorus, however, were based on samples taken in the fall prior to the year of planting.

Fertilizers were applied broadcast 10 days before planting. Among the varieties grown on the different properties were common ones such as Long Red, Geneva John Baer and Ferguson. The planting distance, planting, cultivation, disease and insect control were the responsibility of the grower. Yields were taken at approximately weekly intervals from 18 plants in a 0.012-acre plot and included all marketable fruits reaching maturity by the first frost.

RESULTS AND DISCUSSION

Further Trials and Summary of c_1 and c Values

Table 1 gives the soil test and yield results of the 16 additional trials, and Table 2 shows the computed c_1 and c values. The absolute yields for the different trials varied considerably even when nitrogen, phosphorus and potassium were added in amounts considered to be adequate. However, the soil test values and percentage yields for plots receiving no phosphorus fertilizer indicated that the selected sites represented a satisfactory range in soil phosphorus levels for the purpose of establishing the proportionality constants.

The c_1 values for 66 trials and the c values for 40 comparisons are summarized in Table 3. As shown by the t values, the deviations of the annual mean c_1 values from the general mean (0.00410) for the 6-year

period were significant in 1952 only. The standard deviation (± 0.00219) for a single trial, based on the variation occurring between the 66 trials regardless of year, was slightly higher than the corresponding values for trials conducted in the same year. The standard error of the mean c_1 value for all trials was ± 0.00027.

The appropriate t values show that the deviations of the annual mean c values from the general mean (0.00428) for 40 comparisons were not significant. The standard deviation (± 0.00195) for a single comparison, regardless of year, was similar to the corresponding values obtained in different years. The standard error of the mean c value for all comparisons was ± 0.00031.

TABLE 2.—CALCULATED c_1 AND C VALUES FOR TOMATO TRIALS CONDUCTED IN 1954 AND 1955

Grower	1954				Grower	1955	
	c_1 values	c values*				c_1 values	c values*
		Recom'd	¾ recom'd	½ recom'd			Recom'd
1	0.00400	0.00634	0.00257	0.00424	1	0.00397	0.00260
2	0.00399	0.00545	0.00210	0.00164	2	0.00699	0.00354
3	0.00464	0.00714	0.00500	0.00460	3	0.00594	0.00474
4	0.00400	0.00117	—	—	4	0.00460	0.00668
5	0.00300	0.00755	0.00267	0.00543	5	0.00453	0.00524
6	0.00554	0.00479	0.00649	0.00567	6	0.00393	0.00275
7	0.00331	0.00450	0.00422	0.00571	7	0.00270	0.00215
					8	0.00443	0.00685
					9	0.00482	0.00672

* Based on mean c_1 value of 0.00410 for 1950–1955.

TABLE 3.—SUMMARY OF c_1 AND C VALUES OBTAINED IN DIFFERENT YEARS

Year	No. of comparisons	Mean values for constants	Standard deviation of single variate	t values (P.05)*	
				Obtained	Required
			c_1 values		
1950	11	0.00448	0.00126	0.905	2.228
1951	9	0.00400	0.00147	0.200	2.306
1952	12	0.00321	0.00080	3.179	2.201
1953	18	0.00425	0.00169	0.349	2.110
1954	7	0.00407	0.00084	0.083	2.447
1955	9	0.00466	0.00123	1.273	2.306
General mean	66	0.00410	0.00219		
			c values**		
1953	12	0.00365	0.00221	0.887	2.201
1954	19	0.00459	0.00183	0.596	2.101
1955	9	0.00459	0.00189	0.442	2.306
General mean	40	0.00428	0.00195		

* For comparing annual with general mean.
** Based on mean c_1 value of 0.00410 for 1950–1955.

Despite the variability of the c_1 and c values from trial to trial, (Table 2), the mean values established for the constants are considered to be reasonably satisfactory for predicting the phosphorus fertilizer requirement of the tomato crop in the area when the Bray method for acid-soluble plus adsorbed phosphorus is used.

Use of Constants for Predicting Phosphorus Requirement

Table 4 illustrates the use of the constants in estimating the percentage of maximum yield expected and the amounts of phosphorus fertilizer required for 95 per cent of maximum yield for a range of soil test values. For the purpose of this discussion, maximum denotes the level of yield obtained with adequate fertilization. Without the addition of phosphate, a yield representing 95 per cent of the maximum would be expected only where the soil test value was slightly in excess of 300 lb. P per acre. To attain 95 per cent of maximum production, a broadcast application of 48 lb. P_2O_5 per acre would be required to compensate for each deficit of 50 lb. P per acre in the soil test value.

The yield data for rates of phosphorus based on the c_1 and c values available in 1954 and 1955 lend support to the validity of the constants (Table 1). With amounts of phosphorus recommended for 95 per cent of maximum yield, the corresponding percentage values obtained in the 16 trials ranged from 90 to 102. The average value (96 per cent) was in good agreement with that expected. Additions of phosphate at rates representing only three-quarters of the amounts recommended for 95 per cent of maximum yield resulted in a decrease in the values for percentage yield, the average value for the seven trials in 1954 being 89 per cent. In the present study, the differences between the percentage yields for one-half and three-quarters of the recommended rates were not significant except in one trial.

The experiments reported to date show the need for phosphorus fertilizer for tomatoes in the area. The yields obtained without the addition of phosphate represented less than 80 per cent of the maximum

TABLE 4.—PHOSPHATIC FERTILIZER REQUIREMENTS FOR 95 PER CENT OF MAXIMUM YIELD OF TOMATOES FOR A RANGE OF SOIL TEST VALUES IN PRINCE EDWARD COUNTY, ONTARIO

Soil test (Bray)	Percentage yield without P (c_1 = 0.00410)	Phosphorus requirement (c = 0.00428)
lb.P/ac.	%	lb P_2O_5/ac.
50	37.6	256
75	50.7	232
100	61.1	208
150	75.7	160
200	84.9	112
250	90.6	64
300	94.5	17
350	96.3	0
400	97.7	0

yield in 39 of the 66 trials. In considering phosphorus requirement, attention should be given to management and moisture conditions which may impose limits on the amounts of phosphorus which may be added profitably. For example, the yields obtained with an adequate supply of phosphorus in some of the trials (2, 6, 7 and 12, Table 1) were considerably lower than the average of 15.4 tons per acre. Under such conditions, fertilization for less than 95 per cent of maximum yields may be a more practical objective.

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PREVALENCE OF *HELMINTHOSPORIUM SATIVUM, FUSARIUM CULMORUM* AND CERTAIN OTHER FUNGI IN EXPERIMENTAL PLOTS SUBJECTED TO VARIOUS CULTURAL AND MANURIAL TREATMENTS[1]

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[Received for publication January 18, 1957]

ABSTRACT

Sixty-two genera of micro-fungi were found in the soil of experimental plots during a 7-year period of sampling. Five saprophytic species (*Aspergillus flavipes* (Bain. & Sart.) Thom & Church, *Penicillium chrysogenum* Thom, *P. intricatum* Thom, *P. restrictum* Gilm. & Abbott, and *P. terrestre* Jensen) made up 52.7 per cent of the fungus colonies found on soil-dilution plates of Czapek's medium agar. The total for two parasitic fungi (*Helminthosporium sativum* Pamm., King & Bakke, and *Fusarium culmorum* (W.G. Sm.) Sacc.) usually associated with common root rot of cereals, was only 0.5 per cent.

Variation in soil temperature and rainfall during the soil-sampling period did not affect the number of fungus colonies that appeared on the dilution plates; neither did crop rotation nor soil fertilization. However, the location of a plot in the experimental field did affect the number of colonies of *Penicillium intricatum* and *P. restrictum*, and the pattern of their occurrence, although different for each fungus, was consistent from year to year. Each of the other five fungi studied was recovered from all the plots with about the same frequency. It is suggested that *P. intricatum* and *P. restrictum* are more resistant than the other fungi to ordinary antibiotic agencies of the particular soil considered and are consequently capable of multiplying according to the suitability of the soil habitat.

INTRODUCTION

This investigation, begun in 1936 and terminated in 1942, was a part of a larger project in which a study was made of the soil microflora in relation to the occurrence of common root rot in cereal crops. The larger project was carried on jointly by the Plant Pathology Laboratory, Science Service, at Winnipeg, and the Department of Microbiology, University of Manitoba. Some of the results have already been published (3, 4).

The disease known as common root rot occurs wherever cereal crops are grown. It attacks wheat, barley, and many cultivated grasses quite severely, and to a lesser extent also oats and rye. The fungi most frequently associated with the disease are *Helminthosporium sativum* and *Fusarium culmorum*. Both fungi can invade the host at any stage of its development, *H. sativum* attacking the roots, culms, leaves, inflorescences, and seeds, and *F. culmorum* attacking roots and sometimes the seed. Common root rot may occur in vigorously growing plants but it usually occurs, often in severe form, in plants from seed weakened by frost or by treatment with formaldehyde, or in plants from seed sown too deeply or too thickly, especially when the soil is of low fertility or of an adverse acid or alkaline reaction. The disease is a very complex one, and observations made over a period of many years suggest that conditions unfavourable to growth of the host intensify the disease, and that favourable conditions help to repair the damage already done.

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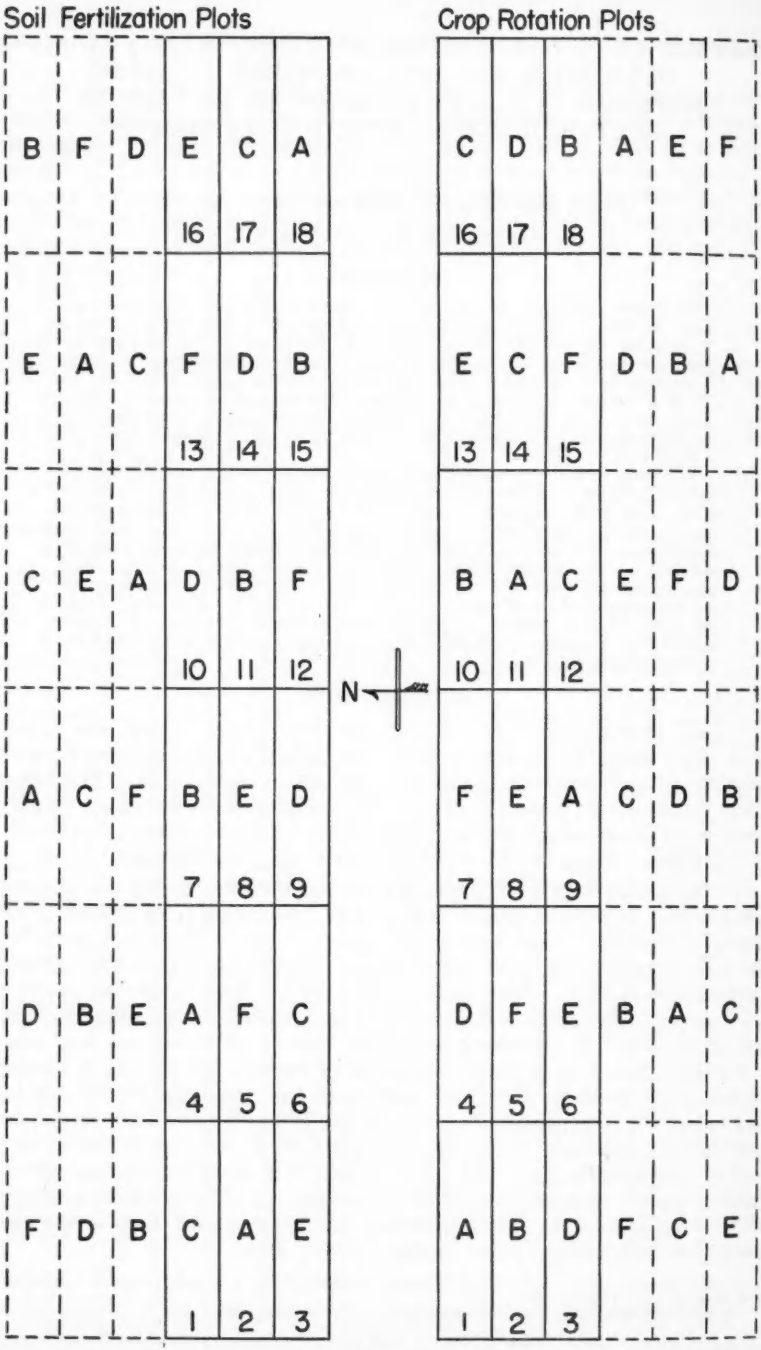
Soil Fertilization Plots
Crop Rotation Plots
B F D E C A
16 17 18
E A C F D B
13 14 15
C E A D B F
10 11 12
A C F B E D
7 8 9
D B E A F C
4 5 6
F D B C A E
1 2 3
C D B A E F
16 17 18
E C F D B A
13 14 15
B A C E F D
10 11 12
F E A C D B
7 8 9
D F E B A C
4 5 6
A B D F C E
1 2 3
N

FIGURE 1. Plan of experimental field. Soil fertilization experiment on left; crop rotation experiment on right. The letters identify the plot treatments and numerals identify the plots referred to in the illustrations following. Plots enclosed by broken lines were not sampled after 1939.

MATERIALS AND METHODS

The experimental field in its original form consisted of two groups of 1/100-acre plots arranged in Latin squares (Figure 1), each group containing 36 plots. One group was used in a comparison of the effects of six crop rotations on the development of common root rot, while the other group was used in a comparison of the effects of six manurial treatments. These crop rotations and treatments were as follows:

Crop rotations

A. Continuous wheat
B. Alternate wheat and summerfallow
C. Wheat, wheat, summerfallow
D. Wheat, wheat, wheat, summerfallow
E. Wheat, wheat, barley and grass, hay, summerfallow
F. Wheat, barley, corn, flax and grass, hay, summerfallow.

Manurial treatments

A. Triple superphosphate (44% P_2O_5)—75 lb. per acre
B. Ammonium phosphate (16-20)—165 lb. per acre
C. Same as B, plus 50 lb. per acre of sulphate of potash (48%)
D. Farmyard manure—15 tons per acre, applied and ploughed under in autumn
E. Same as D, plus 75 lb. per acre of triple superphosphate
F. Check, no fertilizer added.

Samples of soil were taken from these plots at bi-weekly intervals throughout the growing season—from the beginning of June to the end of August. In 1936, 1937, 1938 and 1939, all 72 of the plots were sampled, but, because that amount of sampling and consequent plating was difficult to complete in one day, samples of soil were taken in 1940, 1941, and 1942 from only 18 plots of each group, those outlined by the solid lines in Figure 1. The data discussed in the following sections of this paper refer, therefore, to only three replicates of each crop rotation and manurial treatment, instead of to six as originally intended.

During sampling, a core of soil (6 × 1½ inches) was removed from each of six locations, taken at random, in each plot. The apparatus used was a brass tube sharpened at the lower end and provided with an adjustable footrest to regulate the depth of sampling. A plunger within the tube ejected the soil from the tube after the sample was taken.

The six cores of soil taken from each plot were put together in a clean glass jar which was then closed, and, when the sampling was completed, taken to the laboratory. There the cores of soil were crushed by hand, mixed thoroughly, and sub-samples withdrawn for a moisture test and a microbiological determination. The second sub-sample (equivalent to 25 gm. on a dry basis) was put in a pint jar containing 240 cc. of sterile water and shaken for five minutes by a mechanical shaker. Further dilutions, up to 1:5,000 for fungi, were shaken 25 times by hand because the containers (6-ounce medicine bottles) holding the diluted suspension were too small for the mechanical shaker available.

Czapek's medium agar, acidified with diluted lactic acid (10 cc. of 85% U.S.P.X. per 100 cc. of distilled water) at the rate of 0.5 cc. diluted acid per 100 cc. of agar, was used for culturing fungi. Counts of fungus colonies were made after the culture plates had been incubated for four days at 25-28°C., but the direct identification of fungi on the culture plates, and the transfer of "unknowns" to agar-slants, was delayed until after an additional incubation period of three days at room temperature.

EXPERIMENTAL RESULTS

Number and Kinds of Fungi Isolated from Soil

In all, 76,942 colonies of fungi were counted on the agar plates examined during the course of this investigation. Those recognized fell into 179 species distributed among 62 genera. The genera were as follows: *Absidia*, *Acremoniella*, *Acrostalagmus*, *Aleurisma*, *Alternaria*, *Aspergillus*, *Beauvaria*, *Botrytis*, *Candida*, *Cephalosporium*, *Chaetodiplodia*, *Chaetomium*, *Chaetosphaeronema*, *Cladosporium*, *Coniosporium*, *Costantinella*, *Coniothyrium*, *Curvularia*, *Dendryphium*, *Diplococcium*, *Diplodina*, *Ectosticta*, *Fusarium*, *Geotrichum*, *Gloeosporium*, *Gliocladium*, *Helminthosporium*, *Hormodendron*, *Metarrhizium*, *Microdiplodia*, *Monilia*, *Monotospora*, *Mortierella*, *Mucor*, *Myrotheciella*, *Neottiospora*, *Oidiodendron*, *Paecilomyces*, *Penicillium*, *Periconia*, *Phialophora*, *Phoma*, *Pringsheimia*, *Pullularia*, *Pycnis*, *Pythium*, *Rhizoctonia*, *Rhizopus*, *Rosellinia*, *Sclerotinia*, *Scopulariopsis*, *Septomyxa*, *Sordaria*, *Spicaria*, *Strachybotrys*, *Stemphylium*, *Stysanus*, *Torulopsis*, *Trichoderma*, *Verticicladium*, *Verticillium*, and *Zygorrhynchus*.

Although the experimental plots studied supported a comparatively rich fungus flora, only a few species were truly abundant. For instance, 13 species of fungi, each one accounting for 1 per cent, or more, of the colonies observed, represented 64.4 per cent of the total. The percentage for each of these 13 species was as follows: *Penicillium intricatum* Thom group, 33.7 per cent; *P. terrestre* Jensen, 7.9 per cent; *P. restrictum* Gilm. & Abbott, 4.6 per cent; *Aspergillus flavipes* (Bain. & Sart.) Thom & Church, 3.3 per cent; *P. chrysogenum* Thom group, 3.2 per cent; *Rhizopus nigricans* Ehrenberg, 2.7 per cent; *P. lilacinum* Thom, 1.8 per cent; *Alternaria tenuis* sensu Wiltshire, 1.6 per cent; *Gliocladium roseum* Bainier, 1.5 per cent; *Metarrhizium* sp., 1.2 per cent; *Monotospora Daleae* Mason, 1.1 per cent; *Trichoderma viride* Pers. ex Fr., 1.1 per cent and *P. frequentans* Westling 1.0 per cent. The percentages for the two fungi usually associated with common root rot of cereals were: *Helminthosporium sativum* Pamm., King & Bakke, 0.24 per cent; *Fusarium culmorum* (W.G.Sm.) Sacc., 0.26 per cent.

In the comparisons made later in this paper, consideration is given mostly to the five fungi most abundant in the soil (Table 1). Together these fungi (*Penicillium intricatum*, *P. terrestre*, *P. restrictum*, *P. chrysogenum*, and *Aspergillus flavipes*) accounted for 52.7 per cent of all the fungus colonies observed. Consideration is given also to the fungi *Helminthosporium sativum* and *Fusarium culmorum*, because of their connection with common root rot of cereals. The comparisons are chiefly between the experimental results obtained in 1936 and those obtained in 1942—

TABLE 1.—COMPARATIVE ABUNDANCE OF THE TWO ROOT-ROTTING FUNGI AND THE FIVE MOST COMMON SAPROPHYTIC FUNGI IN EXPERIMENTAL PLOTS AT WINNIPEG DURING THE PERIOD 1936-1942[1]

Fungus	Colony count for year													
	Crop rotation field							Soil fertilization field						
	1936	1937	1938	1939	1940	1941	1942	1936	1937	1938	1939	1940	1941	1942
Aspergillus flavipes	267	321	179	125	116	103	60	325	403	169	142	152	107	50
Fusarium culmorum[2]	30	41	13	5	11	8	0	19	22	31	12	7	3	4
Helminthosporium sativum[2]	5	23	15	18	5	7	6	2	22	40	12	12	7	10
Penicillium chrysogenum	161	348	316	184	173	90	140	44	219	179	150	211	133	120
Penicillium intricatum	1858	3318	2578	1887	1920	1472	1237	1574	2776	1796	1536	1598	1331	1050
Pencillium restrictum	186	638	309	306	244	231	216	135	349	189	142	167	197	201
Penicillium terrestre	187	109	538	303	383	156	2058	445	471	169	504	337	144	854
Total	2704	4798	3948	2828	2752	2067	3717	2544	4262	2579	2498	2484	1922	2289

[1]Total from 504 dilution plates (4 replicate dilution plates × 7 samplings × 18 plots) per year. Dilution 1 : 5000.
[2]Root-rotting fungi.

results obtained at the beginning of one cultural cycle and those obtained at the beginning of a second. Such a comparison was possible because, in both years, all the plots studied happened to be sown to wheat.

Distribution of Fungi within the Experimental Field

It was noticed that, when a count was made of the fungus colonies that appeared on the dilution plates, certain species were consistently more abundant in some plots than in others. Other species were distributed

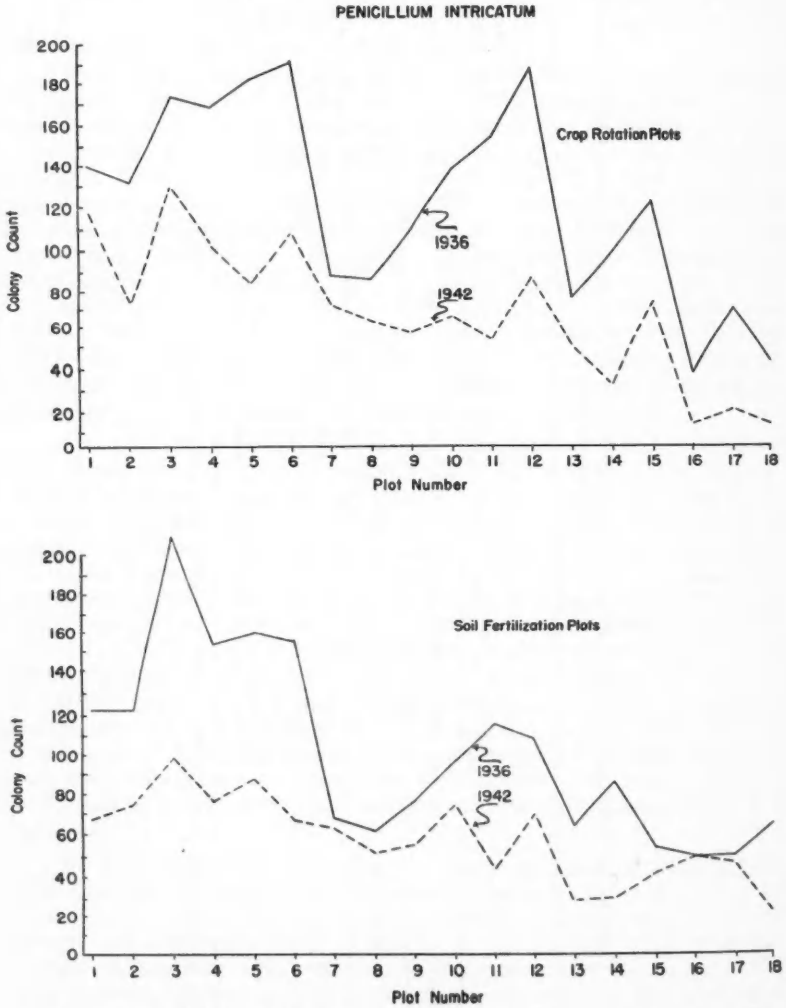

FIGURE 2. *Penicillium intricatum.* Patterns of distribution in experimental field in 1936 and 1942.

more or less uniformly throughout the field. The treatment which the plots received appeared to have no bearing on the population of a fungus species in them.

Penicillium intricatum was one of the fungi showing a definite population pattern. It was found much more frequently in the plots at the

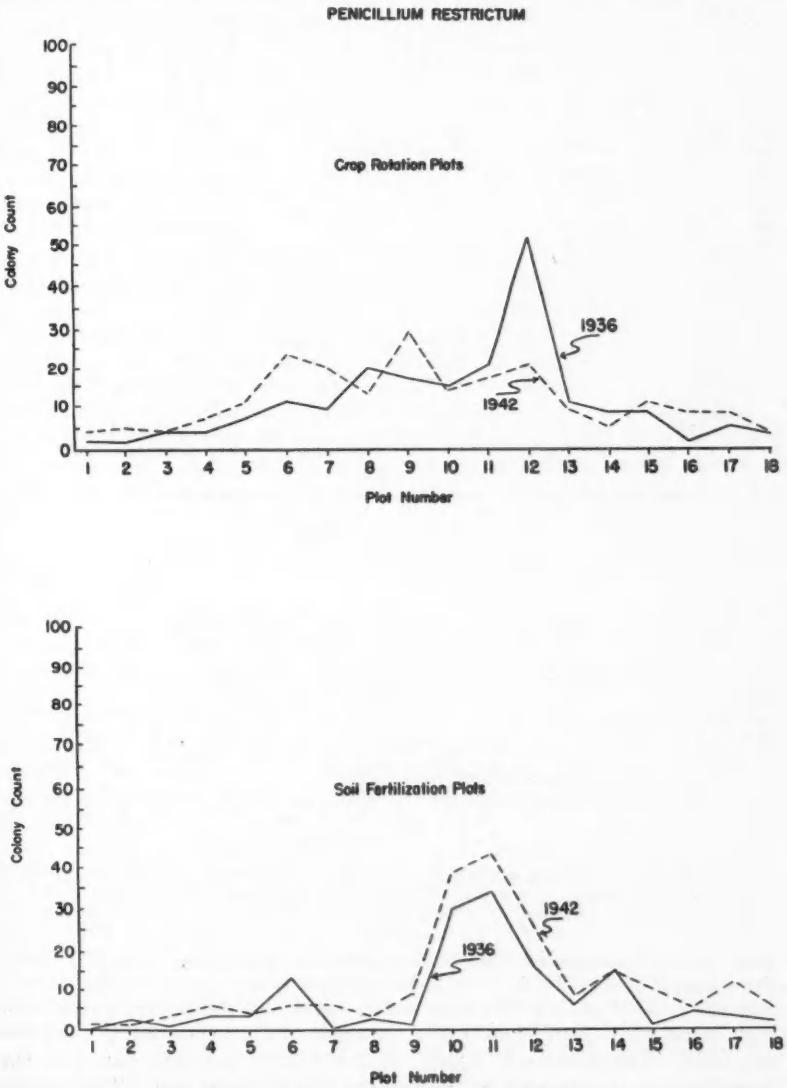

FIGURE 3. *Penicillium restrictum.* Patterns of distribution in experimental field in 1936 and 1942.

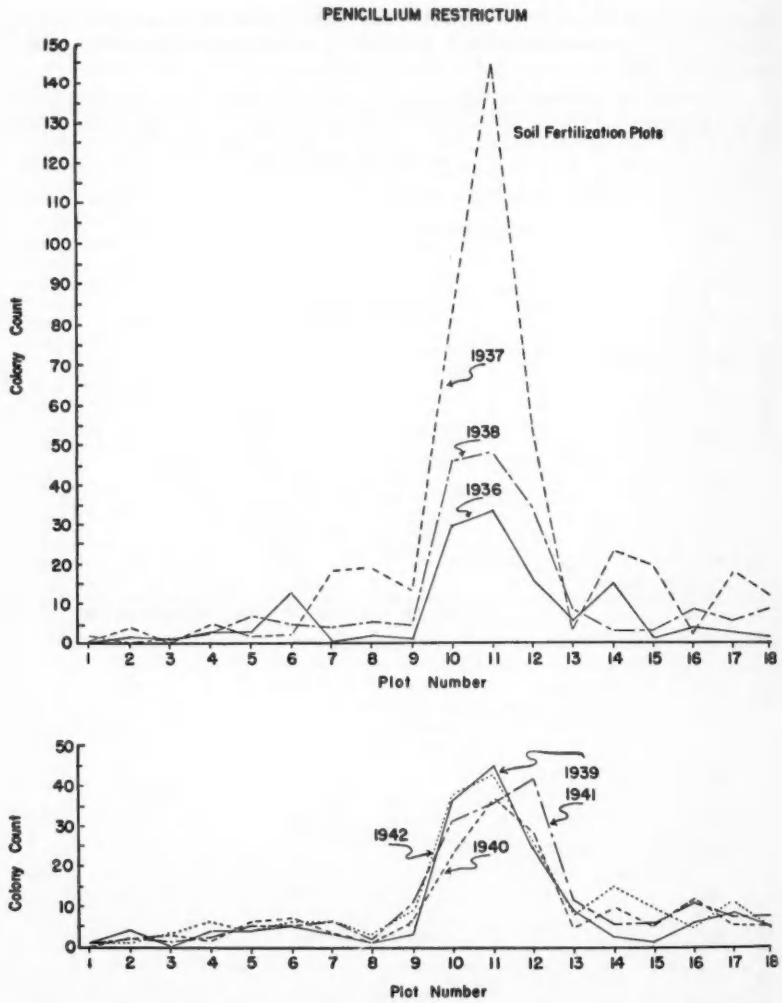

FIGURE 4. *Penicillium restrictum.* Patterns of distribution among soil fertilization series of plots. Upper part of figure shows patterns for 1936, 1937 and 1938. Lower part shows patterns for 1939, 1940, 1941 and 1942.

west end of the experimental field than in the east end. Figure 2 shows the pattern of distribution for 1936 and 1942 only, but a similar pattern was observed in each of the intervening years and the tendency toward a high count of *P. intricatum* in the west end of the experimental field was noticeable in both series of plots. A distribution pattern, quite different from the one just described, was noted for *P. restrictum*. This fungus seemed to prefer the soil in the middle of the experimental field, instead

of that of the west end (Figure 3). Three other soil fungi, namely, *P. terrestre*, *P. chrysogenum* and *Aspergillus flavipes*, were recovered with about the same frequency from all parts of the experimental field. A tendency towards a uniform colonization of the field was observed for *Helminthosporium sativum* and *Fusarium culmorum* also, but the colonies of these two fungi were too few to allow a definite conclusion.

The persistency of soil colonization by certain fungi is illustrated in Figure 4. Here it is shown, for *Penicillium restrictum*, that modification of the nature of the plots by crop rotation and manuring did not affect the density of colonization. Soil temperature and the amount of precipitation during the soil-sampling period did not affect the population of fungi in the plots either. In this case, the coefficients of correlation between the variables were very small indeed, being only +0.1243 for the relation between temperature and number of colonies, and +0.0042 for rainfall and number of colonies.

Rainfall, always an important factor affecting crop yields in Western Canada, markedly influenced the yield of wheat in the experimental plots studied. The total rainfall during the soil-sampling period was 3.55 inches in 1936 and 9.02 inches in 1942. The yield of wheat for the corresponding years was 12.5 and 36.1 bushels per acre. Yet, as already indicated, the variation in rainfall did not affect the total colony count, which in 1936 was 11,267 and in 1942 was 10,449. The total counts for *Helminthosporium sativum* in these years were 7 and 16, and for *Fusarium culmorum* 49 and 4, but, since the colony counts for these two fungi were so small, not much significance can be attached to the differences between them.

Effect of Various Soil Amendments and Crop Rotations on the Population of Fungi in Soil

One of the objects of this investigation was to determine the effect of certain fertilizers and crop rotations on the population of micro-organisms in soil, especially of the fungi associated with common root rots of cereals. A comparison of the effects of different fertilizers could be made every year, but, although this experimentation was commenced in 1936, it was not until 1942 that the first over-all comparison could be made of crop rotations. Also, because in 1942 as in 1936 all the plots in both series were sown to wheat, it was possible to compare the number of fungi in one series of plots with the number in the other.

In comparing the two series of plots with respect to the total count of the seven fungi (*Aspergillus flavipes*, *Fusarium culmorum*, *Helminthosporium sativum*, *Penicillium chrysogenum*, *P. intricatum*, *P. restrictum*, and *P. terrestre*) given the most consideration in this study, it was found that in 1936 the total colony count for the crop rotation plots was 2,975 while for the fertilizer plots it was 2,604. In 1942, the corresponding total counts were 2,226 and 2,260. It seems evident, therefore, that the difference in the way the two series of plots were handled had no effect on the colony count. By comparing the effects of the different crop rotations and fertilizers on the colony count of the seven fungi just named, it was found (Table 2) that in all cases but one (*Aspergillus flavipes*, 1936)

TABLE 2.—EFFECT OF VARIOUS CROP ROTATIONS AND FERTILIZERS ON THE OCCURRENCE OF CERTAIN FUNGI, AND ON THE YIELD OF WHEAT, IN EXPERIMENTAL PLOTS

Experimental field	Plot treatment	Mean colony count[1]														Yield[1] (bu./ac.)	
		Aspergillus flavipes		*Fusarium culmorum*		*Helminthosporium sativum*		*Penicillium chrysogenum*		*Penicillium intricatum*		*Penicillium restrictum*		*Penicillium terrestre*			
		1936	1942	1936	1942	1936	1942	1936	1942	1936	1942	1936	1942	1936	1942	1936	1942
Crop rotation	A	16.6	6.3	3.6	0.0	0.0	0.3	8.0	9.3	136.6	77.0	13.3	16.6	9.0	184.6	10.4	36.8
	B	24.0	2.3	2.0	0.0	0.3	0.3	6.3	5.0	105.0	51.6	6.6	7.3	8.6	153.6	9.9	37.2
	C	15.3	2.3	1.6	0.0	0.6	0.0	4.1	3.6	108.6	45.3	20.3	11.3	10.6	107.3	10.1	38.6
	D	11.6	3.0	0.6	0.0	0.3	0.3	11.3	6.6	138.0	84.6	4.3	6.3	7.3	64.0	9.7	35.6
	E	9.6	3.3	1.3	0.0	0.0	0.3	7.3	8.6	118.3	74.6	14.0	15.0	10.3	84.3	10.8	40.1
	F	10.3	2.6	0.6	0.0	0.0	0.0	5.6	12.6	131.3	77.0	5.6	14.0	12.3	92.0	11.4	40.2
	Sig. diff. (5%)	6.6	DNS[2]	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS
Soil fertilization	A	20.6	4.3	1.6	0.6	0.0	0.0	1.0	3.3	113.3	54.6	2.3	4.0	29.6	58.6	13.5	38.0
	B	13.0	1.3	0.6	0.3	0.3	0.6	2.3	8.6	80.3	50.0	11.6	19.6	48.5	33.6	16.0	37.1
	C	19.6	3.6	0.6	0.3	0.0	0.0	5.3	8.3	110.0	60.3	5.3	6.3	20.6	65.3	14.4	34.7
	D	13.0	1.0	0.3	0.0	0.3	0.3	1.0	9.6	86.3	53.0	15.3	20.6	28.3	44.0	14.3	32.0
	E	21.6	3.0	1.0	0.3	0.3	1.0	3.0	4.6	106.6	67.3	2.3	3.6	13.6	37.0	14.5	31.9
	F	20.3	3.3	2.0	0.0	0.3	0.3	2.0	5.3	111.3	59.0	8.3	12.6	12.6	31.6	14.7	38.1
	Sig. diff. (5%)	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	DNS	17.7	DNS	DNS

[1]Means of three replicate plots. [2]DNS = Difference not significant.

none of the crop rotations had any effect on the colony count. Also, in the fertilizer series of plots, with one exception (*Penicillium terrestre*, 1942), none of the plot treatments had any effect on the colony count. None of the crop rotations or fertilizer plot treatments significantly affected the yield of wheat.

DISCUSSION

The data collected during this investigation indicate that the black clay-loam of the Red River Valley supports a comparatively rich fungus flora of which the most abundantly represented species is *Penicillium intricatum*. However, since the area sampled was small (36/100 acre) the present findings may not apply to the whole of the black clay-loam area.

It is surprising that the colony count for fungi was not affected more than it was by temperature and rainfall, especially in view of the fact that these factors are so important in the determination of crop yields. However, the results obtained by the writer are in accord with those obtained by Brown and Halversen (1) and partly with those obtained by Erdman (2), and consequently they are not peculiar to the Winnipeg area where the soil sampling took place. It is not altogether surprising, however, that varying the plot treatment had practically no effect on the fungus population of Red River Valley soil. The soil of the area investigated is rich in plant nutrients, and so the addition of fertilizer to the soil is of comparatively little value. There are exceptions, of course, such as in a late cold spring, when the supply of available nitrogen is usually low. The finding that the fungus flora of the soil may not be affected by soil treatment is again in accord with the observations of the workers just cited.

One of the most interesting observations made during the present study was that fungi may exhibit different, but quite consistent colonization patterns within an experimental field (Figures 2 and 3). The pattern does not seem to be affected by crop rotation or soil amendment. In the present instance, two fungi, namely *Penicillium intricatum* and *P. restrictum*, were not uniformly distributed throughout the experimental field: the former fungus appeared to prefer the west end of the field while the latter preferred its centre. However, there were other fungi, both saprophytes and parasites, that showed no particular pattern of soil colonization and were distributed fairly uniformly over the field. The different tendencies, in this respect, for seven species of fungi in the soil fertilization series of plots, are illustrated in Figure 5.

How the patterns of colonization arise is not known, but they are probably the result of the individual responses of fungi to their environment. Simmonds and his co-workers (6) found that viable inoculum of the fungus *Helminthosporium sativum*, tends, under field conditions, to become concentrated at or just below the soil surface. The explanation offered was that the fungus is prevented by antibiotic micro-organisms from penetrating more deeply into the soil, while at the soil surface it can maintain itself because sunlight destroys the antibiotic agencies at that level.

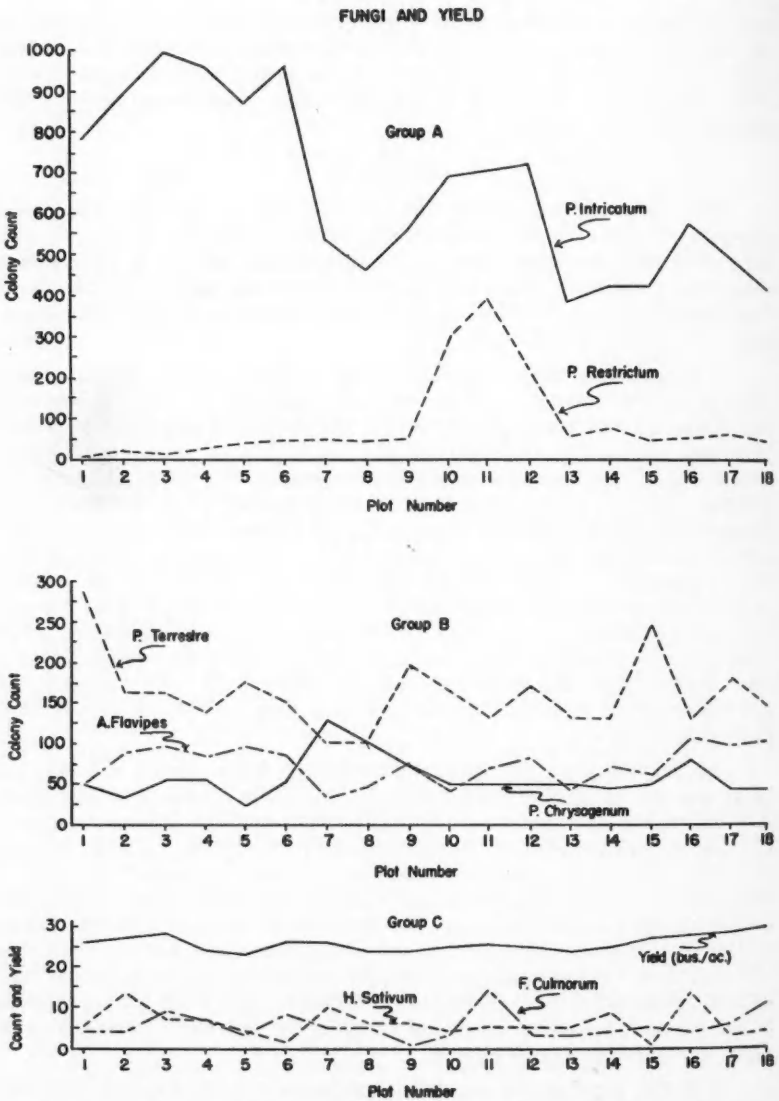

FIGURE 5. Relation of distribution patterns shown by different fungi to the yield of wheat (average of data from the soil fertilization series of plots for the period 1936-42). The *upper part* of figure shows the patterns for two saprophytic species that probably become deeply established in soil; the *middle part* shows the patterns for three saprophytic fungi that are likely to occur chiefly on the soil surface; the *lower part* shows the patterns for two root rotting fungi and for yield. The pattern for yield is applicable to all three parts of this figure.

The fungus is apparently protected from the action of sunlight by its dark pigmentation. The view that antibiotic agencies affect the growth of *H. sativum* in soil has some support in the experimental results obtained by James *et al.* (5) who found that inoculum of an identifiable strain of *H. sativum* deteriorated quickly after introduction into soil, especially when the soil was not sterile.

The suggestion of Simmonds and his co-workers helps to explain why in the present investigation the fungus *Helminthosporium sativum* was found so uniformly distributed over the experimental field. Inoculum confined to the soil surface is freely moved about by wind and rain, and eventually it becomes more or less equalized in concentration throughout the area. The suggestion regarding *H. sativum* may also hold for the other fungi (*Aspergillus flavipes*, *Fusarium culmorum*, *Penicillium chrysogenum* and *P. terrestre*) that were found uniformly distributed over the experimental field. Some of these fungi produce antibiotic substances themselves, but they seem to be confined to the soil surface by the action of more potent products of soil-inhabiting bacteria and actinomycetes. It is more difficult to account for the special colonization patterns shown by *Penicillium intricatum* and *P. restrictum*. It is suggested that these two fungi may be resistant to ordinary antibiotic agencies occurring in soil, and that, being resistant, they are able to establish themselves in soil, multiplying more or less freely according to the suitability of the habitat available.

ACKNOWLEDGEMENTS

The author is deeply indebted to G. R. Bisby, formerly of the Commonwealth Mycological Institute, Kew, Surrey, England, for his unstinted help with the identification of the fungi isolated from soil, and to W. E. Clark, of the Plant Pathology Laboratory, at Winnipeg, Man., for his assistance with the preparation of the illustrations for this paper.

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THE INHERITANCE OF RUST RESISTANCE. III. THE INHERITANCE OF STEM RUST RESISTANCE IN NINE KENYA VARIETIES OF COMMON WHEAT[1]

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[Received for publication January 4, 1957]

ABSTRACT

The inheritance of resistance to races 15B and 56 of stem rust was studied in the varieties Kenya 58, Kenya 117A, Kenya C9906, Kenya 338.AC.2.E.2, Kenya Governor, Kenya B286, Kenya 291.J.1.I.1, Kenya 321.BT.1.B.1 and Kenya 350.AD.9.C.2. The first five varieties had been studied previously and crosses involving them were not repeated. The genetic analysis of the varieties was based on diallel crosses and backcrosses to a susceptible parent, Marquis.

All nine varieties proved to carry *Sr7*, a gene which conditions resistance to race 15B. Four varieties, Kenya 58, Kenya C9906, Kenya 291 and Kenya 350, carry the gene *Sr6*, which conditions a hypersensitive reaction to both race 15B and race 56. In addition, four of the varieties carry *Sr9* and five carry *Sr10*, two genes which produce moderate resistance to race 56. Kenya 338.AC.2.E.2 carries two additional dominant, complementary genes, *Sr11* and *Sr12*, which condition resistance to race 56.

The genes, *Sr9*, *Sr10*, *Sr11* and *Sr12* are important modifiers of the resistance to race 15B conditioned by *Sr7*, with *Sr9* probably having the greatest effect.

INTRODUCTION

In the first two papers of this series, Knott and Anderson (3) and Knott (2), reported on the inheritance of resistance to races 15B and 56 of *Puccinia graminis tritici* Eriks, and Henn. in 16 varieties of *Triticum vulgare* Vill. The varieties Kenya 58, Kenya 117A, Red Egyptian, Egypt Na95, McMurachy, Gabo, Lee, Timstein, Thatcher and Marquis were included in the first paper, and Africa No. 43, Kenya C9906, Kenya 338. AC.2.E.2. (Kenya Farmer), Kenya Governor (Egypt Na101), Veadeiro and Red Egyptian type (P.I. 170910) in the second. Because of the importance of the Kenya varieties in present-day wheat breeding programs, a group of the most rust resistant was selected for the third study. To the five Kenya varieties described in the first two papers, four new ones were added—Kenya B286, Kenya 291.J.1.I.1, Kenya 321.BT.1.B.1 and Kenya 350.AD.9.C.2. It was hoped that these nine would carry most, if not all, of the important genes for rust resistance that are present in the Kenya varieties. As in previous studies, Marquis and Thatcher were included among the parents.

REVIEW OF LITERATURE

Although Kenya varieties have been used extensively in breeding for rust resistance in wheat, relatively few workers have reported on the inheritance of their resistance. The most extensive work has been done by the Australian workers but, unfortunately, it is not yet possible to relate studies with Australian races to those conducted with North American races.

[1] The work reported in this paper was done under a grant from the Canada Department of Agriculture for Extra-mural Research Project EMR-16.

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The literature on Kenya 58 and Kenya 117A has been reviewed by Knott and Anderson (3) who reported on the inheritance of resistance to races 15B and 56 in these two varieties. Kenya 58 was shown to carry one gene, *Sr6*, which conditions a hypersensitive reaction to both races and a second gene, *Sr7*, which conditions resistance to race 15B. Kenya 117A carries *Sr7* and, in addition, two genes, *Sr9* and *Sr10*, which control moderate resistance to race 56. Recently Jones and Ausemus (1) have reported on the inheritance of resistance to race 15B at high temperature in two crosses, Frontana x Mida-Kenya 117A and Kenya 58-Newthatch x Frontana. The Kenya 117A used in Minnesota is not the same as that studied by Knott and Anderson and, in fact, is very like Kenya 58. Jones and Ausemus obtained similar results in the rust tests on both crosses and explained their ratios on a three-factor basis with complex interactions. The genes involved are probably *Sr6*, *Sr7* and a weak gene from Frontana.

Knott (2) studied the inheritance of resistance to races 15B and 56 in Kenya C9906, Kenya 338.AC.2.E.2 and Kenya Governor. His data showed that Kenya C9906 carries *Sr6*. In addition he indicated that Kenya C9906 carries *Sr7*, Kenya 338.AC.2.E.2 carries *Sr7*, *Sr9* and *Sr10*, and Kenya Governor (Egypt Na101) carries *Sr7*. Data which prove the identity of these genes are given in this paper.

In a note on the naming of Kenya 338.AC.2.E.2 as Kenya Farmer, Thorpe (4) reported that one of the parents of the variety was a line from the cross (Bobin x Gaza) x Bobin. More recently Watson and Stewart (5) have suggested that Kenya Farmer derived some of its genes for rust resistance from Gaza.

Wiggin (6) reported on the inheritance of resistance to races 15B and 56 in the variety Kentana 52 which came from the cross Kenya RF324 (Kenya C9906) by Mentana. On the basis of results from crosses between Kentana 52 and the Chinese monosomics, Wiggin concluded that Kentana 52 has two loosely linked genes on chromosome XX, one giving resistance to race 56 and the other to race 15B. It appears more probable, however, that Kentana 52 carries *Sr6* which is known to be on chromosome XX and which gives resistance to both races. In addition Kentana 52 must carry two other genes, one giving resistance to each race. The gene for resistance to race 15B would be *Sr7* and the gene for resistance to race 56 would come from Mentana.

MATERIALS AND METHODS

The Kenya varieties studied were as follows: Kenya 58 (C.I.12471), Kenya 117A (C.I.13140), Kenya C9906 (P.I.118896, also R.F. 324), Kenya 338.AC.2.E.2 or Kenya Farmer (P.I.187165), Kenya Governor (P.I.139599), Kenya B286 (P.I.124738), Kenya 291.J.1.I.1 (P.I.177172), Kenya 321.BT.1.B.1 (P.I.177179) and Kenya 350.AD.9.C.2 (P.I.177185). Seed of Kenya 58 was obtained from the Department of Agronomy and Plant Genetics at the University of Minnesota; Kenya 117A came from the Laboratory of Cereal Breeding at Winnipeg; and the remaining seven varieties were obtained from United States Department of Agriculture, Plant Industry Station, Beltsville, Maryland. For the sake of brevity, in the remainder of the paper the pedigree part of the variety designations is omitted.

The rust resistance of the varieties can be described very briefly. All are resistant to race 15B and all except Kenya Governor are resistant to race 56. Two of them, Kenya 338 and Kenya 321, are resistant to the races of leaf rust prevalent on the Canadian prairies.

The methods used in these studies were similar to those described by Knott and Anderson (3). Diallel crosses were made between Thatcher, Marquis and the nine Kenya varieties except that 15 crosses which had been studied earlier were not repeated. The four varieties which had not been in previous tests, Kenya B286, Kenya 291, Kenya 321 and Kenya 350, were backcrossed to both Thatcher and Marquis. In all, 40 crosses and 8 backcrosses were made.

Rust tests were conducted on the crosses and backcrosses as follows:

1. The F_1 plants from the diallel crosses were tested in the field with race 15B.

2. The F_2 populations from the diallel crosses were tested for field reaction to race 15B and seedling reaction to races 15B and 56.

3. The F_2 families from the backcrosses to Marquis were tested for seedling reaction to races 15B and 56. Representative families were tested for field reaction to race 15B.

The parents were included in all tests.

RESULTS

The rust reaction of the parent varieties used in this study is given in Table 1. The results are those normally obtained at Saskatoon with the isolates of races 15B and 56 used in all the rust tests. Slightly different

TABLE 1.—RUST REACTIONS OF THE PARENT VARIETIES

	Seedling reaction —race 56 (pustule type)	Seedling reaction —race 15B (pustule type)	Field reaction —race 15B (% rust)
Marquis	4	4	40 – 60%
Thatcher	1 – 1$^+$	4	40 – 60%
Kenya 58	0;	0;	0 – T
Kenya 117A	0; – 1$^-$	1$^-$ – 1	0 – T
Kenya C9906	0;	0;	0 – T
Kenya 338	0; – 1$^-$	1$^-$ – 1	0 – T
Kenya Governor	3 – 3$^+$	1$^+$	5 – 30%
Kenya B286	1$^+$	1	0 – T
Kenya 291	0;	0;	0 – T
Kenya 321	0; – 1$^-$	1$^-$ – 1	0 – T
Kenya 350	0;	0;	0 – T

reactions might be obtained with the isolates under changed environmental conditions. With different biotypes, or possibly even different isolates of the same race, the results could be entirely dissimilar.

The genetics of resistance to races 15B and 56 of stem rust have been established for Kenya 58 and Kenya 117A by Knott and Anderson (3) and no further discussion of these varieties will be given. The inheritance of resistance in Kenya C9906, Kenya 338 and Kenya Governor was demonstrated by Knott (2); however, additional data identifying the genes in the three varieties are presented in this paper.

Knott and Anderson (3) noted that with race 15B the gene *Sr6* behaved as a recessive in some crosses but as a dominant in crosses which were homozygous for *Sr7*. This again proved to be true in the crosses reported here. In some cases, however, combinations of other genes produced a high degree of resistance so that it was impossible to determine which plants carried *Sr6*. This accounts for the fact that in some crosses a separation is made between highly resistant and less resistant plants while in other crosses no separation is made.

Kenya C9906

In the paper by Knott (2) it was shown that Kenya C9906 carries the gene *Sr6*, which conditions a hypersensitive reaction to both race 15B and race 56, and a second gene which conditions moderate resistance to race 15B only. Data which prove that this second gene is *Sr7* are given in Table 2.

TABLE 2.—THE RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM THE CROSSES OF KENYA C9906 WITH KENYA 117A AND KENYA 58

Type of test		Number of plants		
		VR	R	S
Kenya C9906 x Kenya 117A F_2				
Seedling tests—race 15B	Observed	79		0
Field tests—race 15B	Observed	60		0
Kenya C9906 x Kenya 58 F_2				
Seedling tests—race 56	Observed	144	0	0
Seedling tests—race 15B	Observed	148	0	0
Field tests—race 15B	Observed	182	0	0

All of the F_2 seedlings from the cross Kenya C9906 x Kenya 117A were at least as resistant to race 15B as the Kenya 117A parent. Since Knott and Anderson (3) have shown that the resistance of Kenya 117A to race 15B is due to *Sr7*, Kenya C9906 must also carry *Sr7*. In field tests with race 15B, the F_2 plants from the same cross were all resistant, although many were not as highly resistant as the two parents. This is undoubtedly due to the segregation of modifiers.

As expected, all F_2 plants from the cross Kenya C9906 x Kenya 58 exhibited the hypersensitive reaction to both races which is conditioned by *Sr6*.

Kenya 338

Knott (2) has shown that in Kenya 338 a single gene conditions resistance to race 15B and two independent genes condition resistance to race 56. The identity of the three genes can be determined from the data in Table 3. In the cross between Kenya 338 and Kenya 117A all of the F_2 plants were highly resistant to both races. Since the resistance of Kenya 117A to race 15B is controlled by the gene *Sr7*, the gene in Kenya 338 must also be *Sr7*. The two genes for resistance to race 56 in Kenya 338 have each been shown to condition a type 2 reaction but together they have an additive effect and condition a fleck to 1^- type of reaction. Knott and Anderson (3) have shown that the genes *Sr9* and *Sr10* in Kenya 117A have the same effect. All of the F_2 seedlings from the cross between the two varieties gave a fleck to 1^- type of reaction. It is probable, therefore, that genes *Sr9* and *Sr10* are common to both varieties.

All of the F_2 plants from the cross between Kenya 338 and Kenya 58 were resistant to race 15B, proving that the two varieties carry *Sr7* in common. However, not all of the plants were as resistant as those from the cross between Kenya 338 and Kenya 117A. The difference is apparently due to the fact that, in the Kenya 117A cross, both varieties carried genes *Sr9* and *Sr10* which modify the resistance conditioned by *Sr7*. In the Kenya 58 cross these genes were segregating and, as a result, although all plants were resistant, some F_2 seedlings gave a type 1^+ reaction and mature plants carried as much as 20 per cent rust. The corresponding

TABLE 3.—THE RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM THE CROSSES OF KENYA 338 WITH KENYA 117A AND KENYA 58

Type of test		Number of plants			Ratio	P
		VR	R-MR	S		
Kenya 338 x Kenya 117A F_2						
Seedling tests —race 56	Observed	176	0	0		
Seedling tests —race 15B	Observed	176	0	0		
Field tests —race 15B	Observed	172	0	0		
Kenya 338 x Kenya 58 F_2						
Seedling tests —race 56	Observed	79	29	1	144:47:1	.30–.50
	Expected	81.75	26.68	.57		
Seedling tests —race 15B	Observed	94	31	0	3:1	1.0
	Expected	93.75	31.25			
Field tests —race 15B	Observed	156		0		

results for the Kenya 117A cross were a type 1 seedling reaction and a trace of rust on mature plants.

Since Thorpe (4) reported that one of the parents of Kenya 338 was a sib of Gabo, a test was made to see if Gabo and Kenya 338 carried genes in common. One hundred and ninety-six seedlings from a cross between Kenya 338 and Gabo were tested with race 56. All of the plants were at least as resistant as Gabo. Knott and Anderson (3) have shown that Gabo's resistance to race 56 is conditioned by the same two dominant complementary genes on chromosome X that condition resistance in Timstein. Kenya 338 must carry both genes. The fact that these two genes were not discovered in the work on Kenya 338 reported by Knott (2) is due to two factors. First, the cross Kenya 338 x Marquis gave sterile, dwarf F_1 plants and no backcrosses could be made on which to base the analysis of Kenya 338. Second, the inheritance of resistance in Kenya 338 was determined from three F_2 populations and the segregations obtained in two of the three, but not in the third, will fit either a 15 : 1 ratio or the 47 : 1 ratio expected with *Sr11* and *Sr12* taken into consideration (assuming 20 per cent crossing over between *Sr11* and *Sr12*).

On the basis of the genotypes hypothesized for Kenya 338 and Kenya 58 the cross between the two should segregate for five genes for resistance to race 56, *Sr6*, *Sr9*, *Sr10*, *Sr11* and *Sr12*. The segregation is a good fit to the expected ratio of 144 very resistant seedlings: 47 moderately resistant: 1 susceptible.

Kenya Governor

Kenya Governor is resistant to race 15B but susceptible to race 56. Knott (2) reported that Kenya Governor carries *Sr7*. Further proof of this is given in Table 4. Both Kenya 117A and Kenya 58 carry *Sr7*. In

TABLE 4.—THE RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM THE CROSSES OF KENYA GOVERNOR WITH KENYA 117A AND KENYA 58.

Type of test		Number of plants			Ratio	P
		VR	R-MR	S		
Kenya Governor x Kenya 117A F_2						
Seedling tests —race 56	Observed	72		6	15:1	.50–.70
	Expected	73.13		4.87		
Seedling tests —race 15B	Observed	202		0		
Field tests —race 15B	Observed	113		0		
Kenya Governor x Kenya 58 F_2						
Seedling tests —race 56	Observed	121	0	42	3:1	.80–.90
	Expected	122.25	0	40.75		
Seedling tests —race 15B	Observed	117	41	0	3:1	.70–.80
	Expected	118.50	39.50			
Field tests —race 15B	Observed	203		0		

the crosses between these two varieties and Kenya Governor, all of the progeny were at least moderately resistant to race 15B. In the tests with race 56, since Kenya Governor is susceptible, only the genes carried by Kenya 117A and Kenya 58 respectively should be segregating in the two crosses. The segregations obtained were good fits to the expected 15 : 1 and 3 : 1 ratios.

Data showing that the crosses of Kenya Governor with Kenya C9906 and Kenya 338 do not segregate for resistance to race 15B have been reported by Knott (2). The results provide additional proof that Kenya Governor carries *Sr7*.

Of the Kenya varieties studied, Kenya Governor has the poorest resistance to race 15B. The reason for this is undoubtedly the fact that Kenya Governor carries only one gene, *Sr7*, for resistance to race 15B and in addition lacks the genes *Sr9* and *Sr10* which are modifiers of *Sr7*.

Kenya B286

Kenya B286 has noticeably less resistance to race 56 than the other Kenya varieties studied (except Kenya Governor which is susceptible). The data from rust tests on F_2 families from the backcross of Kenya B286 to Marquis are given in Table 5. Approximately half the families segregated for resistance to each race, indicating that two independent genes are present, one giving resistance to race 15B and the other to race 56. Both

TABLE 5.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSS OF KENYA B286 TO MARQUIS

		Race 15B		Totals (race 56)	Expected (1:1)	P
		Number of families				
		Seg. 3MR:1S	S			
Race 56	Seg. 3MR:1S	31	24	55[1]	49.5	.20–.50
	S	26	18	44	49.5	
	Totals (race 15B)	57[2]	42	99	99	
	Expected (1:1)	49.5	49.5	99		
	P	.10–.20				

The ratios within segregating families were as follows:

Race 56
[1] 847MR: 292S plants — P for a 3 : 1 = .50 — .70

Race 15B
[2] 692MR: 266S plants — P for a 3 : 1 = .05

(Five atypical families were eliminated from the table)

genes are partially dominant and the segregations within families were satisfactory fits to a ratio of 3 moderately resistant seedlings: 1 susceptible. In the tests with race 15B the separation between heterozygous resistant and susceptible plants was not always clear. Five atypical families, including two with only three and five plants, were eliminated in calculating the totals.

The data from rust tests on crosses involving Kenya B286 are given in Table 6. The figures from crosses which gave identical results have been combined in this and later tables. The five Kenya varieties that have been discussed in this paper all carry the gene *Sr7* for resistance to race 15B. None of the crosses between the five and Kenya B286 segregated for resistance. It is evident that Kenya B286 carries *Sr7*. The varieties Kenya 117A and Kenya 338 have been shown to carry two genes, *Sr9*

TABLE 6.—RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM CROSSES OF KENYA B286 WITH MARQUIS, KENYA 117A, KENYA 58, KENYA C9906, KENYA 338 AND KENYA GOVERNOR

Type of test		Number of plants			Ratio	P
		VR	R-MR	S		
Kenya B286 x Kenya 117A F_2 and x Kenya 338 F_2						
Seedling tests —race 56	Observed	425		0		
Seedling tests —race 15B	Observed	298		0		
Field tests —race 15B	Observed	276	0	0		
Kenya B286 x Kenya 58 F_2 and x Kenya C9906 F_2						
Seedling tests —race 56	Observed	113	29	3	12:3:1	.10–.20
	Expected	108.75	27.19	9.06		
Seedling tests —race 15B	Observed	113	35	0	3:1	.70–.80
	Expected	111	37			
Field tests —race 15B	Observed	187		0		
Kenya B286 x Kenya Governor F_2						
Seedling tests —race 56	Observed	124		30	3:1	.10–.20
	Expected	115.5		38.5		
Seedling tests —race 15B	Observed	134[1]		0		
Field tests —race 15B	Observed	138		0		
Kenya B286 x Marquis F_2 and x Thatcher F_2						
Seedling tests —race 56	Observed	0	263	74	3:1	.20–.30
	Expected		252.75	84.25		
Seedling tests —race 15B	Observed	0	246	94	3:1	.20–.30
	Expected		255	85		

[1] Two plants classified as susceptible were assumed to have come from either stray seeds or outcrosses.

and *Sr10*, for resistance to race 56. The crosses between these two varieties and Kenya B286 did not segregate for resistance. The gene carried by Kenya B286 is, therefore, either *Sr9* or *Sr10*. No critical data to distinguish between these two possibilities are available. However, in backcrosses that are being made to transfer *Sr9* and *Sr10* individually to Marquis, *Sr9* has shown partial dominance. On the other hand, *Sr10* appears to be more nearly recessive and under some environmental conditions the heterozygote is classed as susceptible. The gene carried by Kenya B286 shows a fair degree of dominance and is, therefore, assumed to be *Sr9*.

The crosses of Kenya B286 with Marquis, Thatcher, Kenya 58, Kenya C9906 and Kenya Governor segregated for resistance to race 56 as expected on the basis of the proposed genotypes. The inheritance of resistance in Thatcher is so complicated that it has been ignored in calculating ratios.

Thirteen representative families from the backcross of Kenya B286 to Marquis were tested for field resistance to race 15B. Those families which had been shown by seedling tests to segregate for *Sr7* segregated for resistance in the field. There was some indication that families that were segrating for both *Sr7* and *Sr9* showed more resistance than families segregating only for *Sr7*.

Kenya 291

The data from the backcrosses of Kenya 291 to Marquis are given in Table 7. The tests were run in February during almost continually

TABLE 7.—THE RESULTS OF RUST TESTS ON F_2 FAMILIES FROM THE BACKCROSS OF KENYA 291 TO MARQUIS

		Race 15B				Totals (race 56)	Expected (1:1:1:1)	P
		Number of families						
		Seg. 1VR:3S	Seg. 4VR:9MR:3S	Seg. 3MR:1S	S			
Race 56	Seg. 3 VR:1S	14	11	0	0	25[1]	20.25	.20–.30
	Seg. 12VR:4MR-S	11	12	0	0	23[2]	20.25	
	Seg. MR-S	0	0	7	6	13	20.25	
	S	0	0	9	11	20	20.25	
	Totals (race 15B)	25[3]	23[4]	16[5]	17	81	81	
	Expected (1:1:1:1)	20.25	20.25	20.25	20.25	81		
	P	.30 – .50						

The ratios within segregating families were as follows:

Race 56
[1] 358VR : 123S plants — P for a 3 : 1 ratio = .70 – .80
[2] 341VR : 135MR-S plants — P for a 12 : 4 ratio = .05 – .10

Race 15B
[3] 124VR : 398S plants — P for a 1 : 3 ratio = .50 – .70
[4] 99VR : 193MR : 82S plants — P for a 4 : 9 : 3 ratio = .10 – .20
[5] 201MR : 82S plants — P for a 3 : 1 ratio = .30 – .50

cloudy weather. Due to the low light intensity, rust development was abnormal and many plants did not develop symptoms of infection. The results were, however, sufficiently good to determine which families were segregating. Within families, the separation of plants into classes was difficult, especially with race 56, and in a number of cases no attempt was made to fit the segregations to ratios. Because of a shortage of seed it was possible to retest only a few of the families at a later date. Nevertheless, the mode of inheritance of rust resistance in Kenya 291 can be

TABLE 8.—THE RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM CROSSES INVOLVING KENYA 291.

Type of test		Number of plants			Ratio	P
		VR	R-MR	S		
Kenya 291 x Kenya 58 F_2 and x Kenya C9906 F_2						
Seedling tests —race 56	Observed	252	0	0		
Seedling tests —race 15B	Observed	325	0	0		
Field tests —race 15B	Observed	279	0	0		
Kenya 291 x Kenya 117A F_2 and x Kenya 338 F_2						
Seedling tests —race 56	Observed	251	0	0		
Seedling tests —race 15B	Observed	210	72	0		
	Expected	211.5	70.5		3:1	.80–.90
Field tests —race 15B	Observed	270		0		
Kenya 291 x Kenya B286 F_2						
Seedling tests —race 56	Observed	488		10		
	Expected	490.22		7.78	63:1	.30–.50
Seedling tests —race 15B	Observed	207		0		
Field tests —race 15B	Observed	128		0		
Kenya 291 x Kenya Governor F_2						
Seedling tests —race 56	Observed	103	33	8		
	Expected	108	27	9	12:3:1	.30–.50
Seedling tests —race 15B	Observed	117	47	0		
	Expected	123	41		3:1	.20–.30
Field tests —race 15B	Observed	212		0		
Kenya 291 x Marquis F_2 and x Thatcher F_2						
Seedling tests —race 56	Observed	213	66	23		
	Expected	226.50	56.62	18.88	12:3:1	.10–.20
Seedling tests —race 15B	Observed	92	223	77		
	Expected	98	220.50	73.50	4:9:3	.70–.80

readily analysed from the data which are given in Table 7. Forty-eight, or approximately half the backcross families, segregated for a very resistant (hypersensitive) reaction to both races and it is evident that one gene is responsible. The segregations within families show that the gene is completely recessive with race 15B but completely dominant with race 56. In addition, approximately half the families segregated for moderate resistance to race 15B and approximately half segregated for moderate resistance to race 56. Kenya 291 must, therefore, carry two independent genes conditioning moderate resistance, one to race 15B and the other to race 56.

The identity of the genes in Kenya 291 is apparent from the data on the F_2 populations given in Table 8. In the crosses with Kenya 58 and Kenya C9906, the two varieties which carry *Sr6*, all of the F_2 seedlings gave a hypersensitive reaction to both races. Kenya 291, therefore, has *Sr6*. Similarly in the crosses between Kenya 291 and the four varieties, Kenya 117A, Kenya 338, Kenya B286 and Kenya Governor, which have been shown to carry *Sr7* but not *Sr6*, all of the F2 seedlings were at least moderately resistant to race 15B. Kenya 281 must also carry *Sr7*. Finally, in the crosses of Kenya 291 with Kenya 117A and Kenya 338, both of which carry *Sr9* and *Sr10*, all of the F_2 progeny were at least moderately resistant to race 56. However, the cross of Kenya 291 with Kenya B286, which is assumed to carry only *Sr9*, segregated for resistance to race 56. If Kenya B286 carries *Sr9* then Kenya 291 must carry *Sr10*. The F_2 progeny from the crosses of Kenya 291 with Marquis and Thatcher segregated as expected on the basis of the genotype proposed.

Fifteen representative families from the backcross of Kenya 291 to Marquis were tested in the field for resistance to race 15B. Each family that segregated for resistance in the seedling stage segregated for field

TABLE 9.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSS OF KENYA 321 TO MARQUIS

		Race 15B		Totals (race 56)	Expected (3:1)	P
		Number of families				
		Seg.3MR:1S	S			
Race 56	Seg.	29	18	47	51	.20–.30
	S	11	10	21	17	
	Totals (race 15B)	40[1]	28	68	68	
	Expected (1:1)	34	34	68		
	P	.10 – .20				

[1] The ratio within the segregating families was as follows:
669MR : 246S plants P for a 3 : 1 ratio = .10 – .20

TABLE 10.—THE RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM CROSSES INVOLVING KENYA 321

Type of test		Number of plants			Ratio	P
		VR	R-MR	S		
Kenya 321 x Kenya 117A F_2 and x Kenya 338 F_2						
Seedling tests —race 56	Observed	349		0		
Seedling tests —race 15B	Observed	311	0	0		
Field tests —race 15B	Observed	317	0	0		
Kenya 321 x Kenya 58 F_2 and x Kenya C9906 F_2						
Seedling tests —race 56	Observed	133	38	4		
	Expected	131.25	41.02	2.73	48:15:1	.50–.70
Seedling tests —race 15B	Observed	142	44	0	3:1	.50–.70
	Expected	139.5	46.5			
Field tests —race 15B	Observed	363		0		
Kenya 321 x Kenya Governor F_2						
Seedling tests —race 56	Observed	107		8		
	Expected	107.81		7.19	15:1	.70–.80
Seedling tests —race 15B	Observed	113		0		
Field tests —race 15B	Observed	189[1]		0		
Kenya 321 x Kenya B286 F_2						
Seedling tests —race 56	Observed	411[2]		0		
Seedling tests —race 15B	Observed	189		0		
Field tests —race 15B	Observed	221		0		
Kenya 321 x Kenya 291 F_2						
Seedling tests —race 56	Observed	141		0		
Seedling tests —race 15B	Observed	162		0		
Field tests —race 15B	Observed	166		0		
Kenya 321 x Marquis F_2 and x Thatcher F_2						
Seedling tests —race 56	Observed	341		25		
	Expected	343.13		22.87	15:1	.50–.70
Seedling tests —race 15B	Observed	0	209	65		
	Expected		205.5	68.5	3:1	.50–.70

[1] One plant which carried 40% rust was assumed to be an accidental outcross and is not included in the total.

[2] One atypical family of 24 plants was eliminated from the figures.

resistance. As expected, the most resistant plants were obtained in families segregating for both *Sr6* and *Sr7*. In families segregating only for *Sr6* the resistance was a little better than in families segregating only for *Sr7*.

Kenya 321

The results of rust tests on the F_2 families from the backcross of Kenya 321 to Marquis are given in Table 9. When tested with race 15B approximately half the backcross families segregated for resistance and half were susceptible. When tested with race 56 approximately three-fourths of the families segregated and one fourth were susceptible. The data indicate that Kenya 321 carries one gene for resistance to race 15B and two additional independent genes for resistance to race 56. The gene conditioning resistance to race 15B is partially dominant and in segregating families a satisfactory fit to a ratio of 3 moderately resistant seedlings (type 1 — 3^- pustules): 1 susceptible was obtained. In the tests with race 56 the segregations within families were not clear and the results were not fitted to ratios. It was evident, however, that both genes were partially dominant and conditioned a type 2 — 2^+ reaction when homozygous.

The genes carried by Kenya 321 are easily identified from the F_2 data given in Table 10. In crosses of Kenya 321 with the seven Kenya varieties, all of which have been shown to carry *Sr7*, every F_2 plant was at least moderately resistant to race 15B. The gene in Kenya 321 is, therefore, *Sr7*. In two varieties, Kenya 117A and Kenya 338, resistance to race 56 has been shown to be due to the genes *Sr9* and *Sr10*. In the crosses between these two varieties and Kenya 321 the F_2 seedlings were all as resistant to race 56 as the parents. If Kenya 321 has only one gene in common with the other two varieties, some of the segregates should have been less resistant than the parents. It is reasonable to assume that the two genes in Kenya 321 are *Sr9* and *Sr10*. As would be expected, the crosses between Kenya 321 and the two varieties Kenya B286 and Kenya 291, which are presumed to carry *Sr9* and *Sr10*, respectively, did not segregate for resistance to race 56. The segregation in the F_2 populations from the crosses of Kenya 321 with Kenya 58 and Kenya C9906 fitted the 48 : 15 : 1 ratio expected on the basis of the genotypes postulated for the parents. Similarly, the segregation in the F_2 populations from crosses of Kenya 321 with Marquis, Thatcher and Kenya Governor, which are susceptible to race 56, fitted the expected 15 : 1 ratio.

Fourteen families from the backcross of Kenya 321 to Marquis were tested in the field for resistance to race 15B. All the families which had segregated for seedling resistance to race 15B also segregated for field resistance.

Kenya 350

The results of rust tests on the F_2 families from the backcross of Kenya 350 to Marquis are given in Table 11. The data are very similar to those obtained with Kenya 291. Approximately half the families segregated for a very resistant (hypersensitive) reaction to both races. In addition, approximately half the families segregated for moderate resistance (type

1-3⁻ pustules) to race 15B and half segregated for moderate resistance (type 2-3 pustules) to race 56. The results indicate the presence of three independent genes. One gene conditions a hypersensitive reaction to both races but the segregations within families show that it is recessive with race 15B and dominant with race 56. The other two genes are partially dominant and each conditions resistance to one race and not to the other. The segregations within families were reasonably clear except for those involving the gene for moderate resistance to race 56. No attempt was made to fit the latter segregations to ratios.

The identity of the three genes in Kenya 350 is readily determined from the data on F_2 populations given in Table 12. All of the F_2 plants from crosses between Kenya 350 and the three varieties which carry *Sr6*, Kenya 58, Kenya C9906 and Kenya 291, were very resistant to both races. The gene in Kenya 350 which conditions a hypersensitive type of reaction is, therefore, *Sr6*. The crosses of Kenya 350 with Kenya 117A, Kenya B286, Kenya 321, Kenya 338 and Kenya Governor gave F_2 plants that were all at least moderately resistant to race 15B. Since in these varieties resistance to race 15B is conditioned by the gene *Sr7*, Kenya 350 must carry *Sr7*. As was the case with Kenya 291, the crosses of Kenya 350 with Kenya 321 and Kenya 338 did not segregate for resistance to race 56, whereas the cross with Kenya B286 did segregate, although only one susceptible plant was obtained. It appears, therefore, that Kenya 350 carries *Sr10*. In the cross of Kenya 350 with Kenya 117A, 11 families were tested and 8 did not segregate for resistance. However, in three

TABLE 11.—RESULTS OF SEEDLING TESTS ON F_2 FAMILIES FROM THE BACKCROSS OF KENYA 350 TO MARQUIS

		Race 15B				Totals (race 56)	Expected (1:1:1:1)	P
		Number of families						
		Seg. 1VR: 3S	Seg. 4VR: 9MR: 3S	Seg. 3MR: 1S	Susc.			
Race 56	Seg. 3VR:1S	9	8	0	0	17[1]	19.25	
	Seg. 12VR:4MR-S	10	9	0	0	19[2]	19.25	.70–.80
	Seg. MR-S	0	0	10	8	18	19.25	
	S	0	0	10	13	23	19.25	
	Totals (race 15B)	19[3]	17[4]	20[5]	21	77	77	
	Expected (1:1:1:1)	19.25	19.25	19.25	19.25	77		
	P	.90 – .95						

The ratios within segregating families were as follows:

Race 56
[1] 259VR : 103S plants — P for a 3 : 1 ratio = .10 – .20
[2] 280VR : 114MR-S plants — P for a 12 : 4 ratio = .05 – .10

Race 15B
[3] 105VR : 342S plants — P for a 1 : 3 ratio = .30 – .50
[4] 85VR : 178MR : 77S plants — P for a 4 : 9 : 3 ratio = .10 – .20
[5] 266MR : 108S plants — P for a 3 : 1 ratio = .05 – .10

TABLE 12.—THE RESULTS OF RUST TESTS ON F_2 POPULATIONS FROM CROSSES INVOLVING KENYA 350

Type of test		Number of plants			Ratio	P
		VR	R-MR	S		
Kenya 350 x Kenya 58 F_2, x Kenya C9906 F_2 and x Kenya 291 F_2						
Seedling tests —race 56	Observed	292	0	0		
Seedling tests —race 15B	Observed	455	0	0		
Field tests —race 15B	Observed	540	0	0		
Kenya 350 x Kenya 117A F_2						
Seedling tests —race 56	Observed	283		7[1]		
	Expected	290		0		
Seedling tests —race 15B	Observed	131	37	0		
	Expected	126	42		3:1	.30–.50
Field tests —race 15B	Observed	108		0		
Kenya 350 x Kenya 338 F_2 and x Kenya 321 F_2						
Seedling tests —race 56	Observed	158	56	0		
	Expected	160.5	53.5		3:1	.50–.70
Seedling tests —race 15B	Observed	154	51	0		
	Expected	153.75	51.25		3:1	1.0
Field tests —race 15B	Observed	206		0		
Kenya 350 x Kenya B286 F_2						
Seedling tests —race 56	Observed	151		1		
	Expected	149.62		2.38	63:1	.30–.50
Seeding tests —race 15B	Observed	124		0		
Field tests —race 15B	Observed	113		0		
Kenya 350 x Kenya Governor F_2						
Seedling tests —race 56	Observed	55	18	3		
	Expected	57	14.25	4.75	12:3:1	.30–.50
Seedling tests —race 15B	Observed	58	19	0		
	Expected	57.75	19.25		3:1	1.0
Field tests —race 15B	Observed	233		0		
Kenya 350 x Marquis F_2 and x Thatcher F_2						
Seedling tests —race 56	Observed	114	33	13		
	Expected	120	30	10	12:3:1	.30–.50
Seedling tests —race 15B	Observed	59	104	43		
	Expected	51.50	115.88	38.62	4:9:3	.20–.30

[1] These seven plants were obtained in three of eleven families tested and are assumed to be atypical.

families tested under poor light conditions a total of seven plants were classified as susceptible. Because these results are contrary to the genotypes hypothesized for Kenya 117A and Kenya 350 on the basis of the other data, they are assumed to be abnormal and possibly due to misclassification. The segregations obtained in the crosses of Kenya 350 with Marquis and Thatcher fitted the expected ratios.

Fourteen families from the backcross of Kenya 350 to Marquis were tested in the field for resistance to race 15B. Each family that segregated for seedling resistance segregated in the field and there was no indication of the presence of genes conditioning only a mature plant resistance.

DISCUSSION

The Kenya varieties described in this paper are among those which have been most rust resistant in North America and have been used most extensively in wheat breeding programs. The data show that for resistance to races 15B and 56, the varieties carry various combinations of four genes and all have one gene, *Sr7*, in common. The genotype of each variety is listed in Table 13. There is no doubt that the Kenya varieties are closely interrelated and many derive their resistance from Kenya 58, Kenya 117A, or both. At the present time North American wheat breeders are most interested in resistance to race 15B. The present results suggest the possibility that the older Kenya varieties are sources of only two genes conditioning resistance to this race.

Since the Kenya varieties studied all carry *Sr7*, the various crosses between them were homozygous for *Sr7* but segregated for other genes. An examination of the percentage rust carried by F_2 plants from the different crosses proved interesting. A compilation of field tests with race 15B is given in Table 14. The crosses are listed according to the genotype of F_1 plants with genes for which they were homozygous susceptible being omitted. Different crosses which resulted in the same F_1 genotype proved to be surprisingly uniform and the results were bulked. For comparison, the percentage rust is given for Marquis, which is susceptible to both races 15B and 56, and for Kenya Governor which carries *Sr7* for resistance to race 15B, but has no other genes for resistance to the two races. Even genetically pure stocks of Kenya Governor are somewhat variable and show

TABLE 13.—PROBABLE GENOTYPES OF THE NINE KENYA VARIETIES

Variety	Genotype					
Kenya 58	*Sr6Sr6*	*Sr7Sr7*				
Kenya 117A		*Sr7Sr7*	*Sr9Sr9*	*Sr10Sr10*		
Kenya C9906	*Sr6Sr6*	*Sr7Sr7*				
Kenya 338		*Sr7Sr7*	*Sr9Sr9*	*Sr10Sr10*	*Sr11Sr11*	*Sr12Sr12*
Kenya Governor		*Sr7Sr7*				
Kenya B286		*Sr7Sr7*	*Sr9Sr9*[1]			
Kenya 291	*Sr6Sr6*	*Sr7Sr7*		*Sr10Sr10*[1]		
Kenya 321		*Sr7Sr7*	*Sr9Sr9*	*Sr10Sr10*		
Kenya 350	*Sr6Sr6*	*Sr7Sr7*		*Sr10Sr10*[1]		

[1] The identity of these three genes is not completely proven by the data.

TABLE 14.—THE RESULTS OF FIELD TESTS WITH RACE 15B ON F_2 POPULATIONS FROM CROSSES BETWEEN THE KENYA VARIETIES

(The crosses are grouped according to the genotype of the F_1 plants).

	Genotype of variety or F_1						Number and percentage of F_2 plants with the following percentage rust							Total
							0–1	5	10	20	30	40	50	60	
1	Susceptible—Marquis											29(56.9)	18(35.3)	4(7.8)	51
2		*Sr7Sr7*—K. Governor						4(17.4)	3(13.0)	11(47.8)	5(21.7)				23
3		*Sr7Sr7*	*Sr9sr9*				82(55.4)	26(17.6)	29(19.6)	8(5.4)	3(2.0)				148
4		*Sr7Sr7*	*Sr9sr9*	*Sr10sr10*			213(71.2)	36(12.0)	34(11.4)	14(4.7)	2(0.7)				299
5		*Sr7Sr7*	*Sr9Sr9*	*Sr10sr10*			289(93.8)	15(4.9)	3(0.9)	1(0.3)					308
6		*Sr7Sr7*	*Sr9Sr9*	*Sr10sr10*	*Sr11sr11*	*Sr12sr12*	188(99.5)	1(0.5)							189
7		*Sr7Sr7*	*Sr9Sr9*	*Sr10Sr10*			105(95.5)	5(4.5)							110
8		*Sr7Sr7*	*Sr9Sr9*	*Sr10Sr10*	*Sr11sr11*	*Sr12sr12*	378								378
9	*Sr6sr6*	*Sr7Sr7*					100(49.3)	31(15.3)	35(17.2)	32(15.8)	5(2.5)				203
10	*Sr6sr6*	*Sr7Sr7*	*Sr9sr9*				328(84.3)	23(5.9)	25(6.4)	10(2.6)	3(0.8)				389
11	*Sr6sr6*	*Sr7Sr7*		*Sr10sr10*			327(73.2)	40(8.9)	48(10.7)	29(6.5)	3(0.7)				447
12	*Sr6sr6*	*Sr7Sr7*	*Sr9sr9*	*Sr10sr10*			584(88.0)	29(4.4)	36(5.4)	13(2.0)	2(0.2)				664
13	*Sr6sr6*	*Sr7Sr7*	*Sr9sr9*	*Sr10sr10*	*Sr11sr11*	*Sr12sr12*	150(96.1)	4(2.6)	1(0.6)	1(0.6)					156
14	*Sr6sr6*	*Sr7Sr7*		*Sr10Sr10*			218(90.4)	9(3.7)	10(4.1)	4(1.7)					241
15	*Sr6sr6*	*Sr7Sr7*	*Sr9sr9*	*Sr10Sr10*			675(91.3)	32(4.3)	22(3.0)	10(1.4)					739
16	*Sr6sr6*	*Sr7Sr7*	*Sr9sr9*	*Sr10Sr10*	*Sr11sr11*	*Sr12sr12*	313(95.7)	8(2.5)	4(1.2)	2(0.6)					327
17	*Sr6Sr6*	*Sr7Sr7*					181(99.5)	1(0.5)							182
18	*Sr6Sr6*	*Sr7Sr7*		*Sr10sr10*			630								630
19	*Sr6Sr6*	*Sr7Sr7*		*Sr10Sr10*			189								189

from 5–30 per cent rust. In the first part of the table (lines 3–8) the crosses are listed which were homozygous for *Sr7* but differed in the genes present for resistance to race 56. From line 3 it is evident that in the one cross which segregated for *Sr9* over half the plants carried 0-1 per cent rust whereas no plants of Kenya Governor were this resistant. The gene *Sr9* is almost certainly, therefore, a major modifier of the resistance conditioned by *Sr7* and it is probable that it is the modifier reported by Knott (2) in Kenya 338. When both *Sr9* and *Sr10* were segregating, an even greater proportion of the plants had 0-1 per cent rust (line 4). Apparently, *Sr10* also has a modifying effect on the action of *Sr7*. A comparison of the modifying action of *Sr9* and *Sr10* can be made from the results in lines 10 and 11. The genotype of the F_1 parent plants was identical except that one group was heterozygous for *Sr6* and *Sr9* and the other group for *Sr6* and *Sr10*. It is apparent that the F_2 progeny of the first group of plants were more resistant than those of the second. Consequently, *Sr9* is a somewhat stronger modifier than *Sr10*. Throughout the table it is evident that the addition of genes *Sr11* and *Sr12* increases the degree of resistance shown by the F_2 plants. These two genes are also modifiers of resistance to race 15B although by themselves they have little effect.

The crosses listed in the middle section of the table (lines 9-16) were not only homozygous for *Sr7* but also segregated for the second gene conditioning resistance to race 15B, *Sr6*. As would be expected, the presence of *Sr6* resulted in many plants having little or no rust (line 9). Within this group of crosses the same modifying action of *Sr9* and *Sr10* is apparent. When both *Sr6* and *Sr7* were homozygous the crosses essentially did not segregate (lines 17-19).

One of the chief difficulties in studies on the genetics of rust resistance is determining which plants are resistant and which susceptible. For plant breeding purposes it is satisfactory to set some arbitrary division, for example, deciding that all seedlings having a reaction of type 2 or better are resistant. Unfortunately, such a classification is usually not genotypic. All of the genes reported in this series of papers are at least partially dominant and for several of them the heterozygote conditions a reaction that is borderline between a type 2 and a type 3. In such cases it is essential to determine the reaction of the heterozygotes in order to include all of them in either the resistant or the susceptible class. A good example is *Sr7*. In some crosses the homozygote conditions a type 1-1^+ reaction with considerable yellowing at the leaf tip. The heterozygote, however, gives anywhere up to a large type 3 pustule but the typical yellowing is still present. With *Sr7*, good 3 : 1 ratios are obtained only if all plants showing the yellowing are included in the resistant class. Some of the variability in the expression of *Sr7* is undoubtedly due to modifiers. Varieties carrying *Sr7* have been crossed and backcrossed five times to Marquis, selecting for resistance to race 15B in each F_1 generation. As the backcrossing proceeded selection became more difficult. When the lines were selfed after the fifth backcross, the best plants recovered were classified as 3^- although they did show considerable yellowing. To recover good resistance to race 15B it will be necessary to add some of the modifying

genes such as *Sr9* and *Sr10*. Similar backcrosses to Thatcher were somewhat more resistant to race 15B which suggests that Thatcher carries genes modifying the action of *Sr7*. It is logical to suppose that these modifiers are the genes which condition Thatcher's resistance to race 56.

It is evident that the inheritance of rust resistance is extremely complex. In a wheat breeding program it would be desirable and, in some cases essential, to incorporate a number of genes into one rust-resistant variety. By so doing, resistance would be provided to more races and resistance to individual races would probably be increased.

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SPRAYING TOMATOES FOR THE CONTROL OF LEAF SPOT, EARLY BLIGHT AND LATE BLIGHT[1]

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[Received for publication November 26, 1956]

ABSTRACT

Tomato leaf spot, early blight, and late blight were controlled effectively in the Ottawa district by six applications of the fixed copper COCS 55 or of Manzate (maneb). The split schedule consisting of three sprays with Manzate, followed by three sprays with COCS 55, or the tank mixture of these two fungicides, gave results comparable to those obtained with each of them alone. Some of the fungicides tested showed a degree of specificity in the control of certain diseases.

INTRODUCTION

The introduction of new organic fungicides suitable for the control of certain fungus diseases of vegetables made it desirable to initiate in 1953 an experiment designed to test a number of these materials for their effectiveness against tomato diseases. Another major aim of this project was to re-assess the recommendations for the use of split schedules of organic and copper fungicides, usually three applications of the former followed by three of the latter.

The use of an organic fungicide in the first half of a split schedule is intended to control such diseases as leaf spot, early blight and anthracnose, and that of a copper fungicide, either Bordeaux mixture or a fixed copper, in the last half, is for the control of late blight. This type of schedule has been recommended in the United States and Canada for several years (1, 2, 3). Some new organic fungicides, such as Vancide Z-65, Vancide F-956W, Vancide F-995W, Vancide ME-4698, Captan, and Manzate, having recently been introduced, it was felt desirable to test these materials singly and in combination with the fixed copper fungicides in either tank mixtures or in split schedules.

MATERIALS AND METHODS

The number of plots laid out during each of the three years varied with the total number of treatments. Each plot consisted of 40 plants of the variety Geneva John Baer, arranged in four rows, 4 feet apart, and with 10 plants 4 feet apart in each row. All the treatments were replicated four times, and each replicated plot occurred once in each of four ranges, its position relative to the other plots being randomized in each range. A roadway wide enough to accommodate the tractor-drawn sprayer was left between the ends of the ranges. The following fungicides, singly,

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in split schedules, or in tank mixtures, were employed one or more seasons:—

Captan (N-trichloromethylthio)—4—cyclohexene—1, 2-dicarboximide
COCS 55 (Copper oxychloride sulphate)
Manzate (manganese ethylene bisdithiocarbamate) (maneb)
Tricop (tribasic copper sulphate)
Vancide Z65 (zinc dimethyldithiocarbamate (ziram) and 2-mercaptobenzothiazole)
Vancide F-956 W (ferric dimethyldithiocarbamate (ferbam) and 2-mercaptobenzothiazole)
Vancide F-995 W (manganese dimethyldithiocarbamic acid and 2-mercaptobenzothiazole)
Vancide ME-4698 (Vancide F-956W and Vancide F-995W)
Zerlate (zinc dimethyldithiocarbamate) (ziram).

The various spray materials were applied with a 50-gal. power take-off sprayer at approximately 250-lb. pressure, and with a 6-nozzle spray broom. The estimated rate of application was 150 gallons per acre during the first half of the season when the plants were small, and over 200 gallons per acre when the crop had set most of its fruit.

In each of the three years, it was found necessary to make one application of 50 per cent wettable DDT, 2 lb. in 100 gal., when the tomato hornworm, *Phlegethontius quinquemaculatus* (Haw.), appeared on the vines. Spraying with fungicides was commenced about July 15, after the plants had set most of their fruit, and continued at 10-day intervals until harvest. In 1953 and 1954, six applications were needed, but four were put on in 1955, an extremely hot and dry year.

TABLE 1—COMPARISON OF THE EFFICIENCY OF VARIOUS FUNGICIDES AND FUNGICIDE COMBINATIONS FOR THE CONTROL OF LEAF SPOT (*Septoria lycopersici*) ON GENEVA JOHN BAER TOMATOES DURING 1953–1955

Treatment	Average number of leaf spot lesions per 10 leaves*		
	1953	1954	1955
No spray except one application of DDT for the control of hornworms	1641.0	4976.3	700.8
COCS 55 (6 lb. in 80 gal. of water)	15.0	19.3	5.0
Vancide Z-65 (2 lb. " " " ")	79.3	564.5	4.8
Tank-mixed COCS 55 (3 lb.) and Vancide Z-65 (1 lb.) in 80 gal. water	5.8	30.8	2.8
Vancide Z-65 (2–80)[1] for first half of schedule; COCS 55 (6–80) for second half	—	632.3	6.0
Tricop (6–80)[2]	—	66.3	10.3
Manzate (2–80)[1]	6.8	8.8	3.0
Tank-mixed Tricop (3 lb.) and Manzate (1 lb.) in 80 gal. water	15.3	15.8	4.8
Manzate (2–80)[1] for first half of schedule; Tricop (6–80)[2] for second half	—	15.3	1.5
Vancide F-995W (2–80)[1]	—	459.0	15.8
Vancide F-956W (2–80)[1]	—	1555.8	7.5
Vancide ME-4698 (mixture of F-995W & F-956W) (2–80)[1]	—	—	6.0
Zerlate (2–80)[1]	—	535.5	—
Captan (2–80)[1]	—	—	11.8
	L.S.D.'s at the 1% level		
	1953	326.1	
	1954	479.2	
	1955	342.5	

* Average of 4 plots receiving each treatment

[1] 2 lb. in 80 gal. water
[2] 6 lb. in 80 gal. water

Repeated attempts were made to induce a uniform development of four fungus diseases, leaf spot, early blight, late blight, and anthracnose, by inoculating the plants with spore suspensions of their respective causal organisms, namely *Septoria lycopersici* Speg., *Alternaria solani* (Ell. & Mart.) Sor., *Phytophthora infestans* (Mont.) de Bary, and *Colletotrichum phomoides* (Sacc.) Chester, during or immediately after periods of rain.

The harvesting of ripe fruits commenced usually in mid-August. The picking was done twice a week during the height of the harvest, but only once a week at the beginning and at the end of the season. Records were taken of the number and the weight of diseased and healthy fruits from the two inner rows (16 plants) of each plot. During the early part of September, a count was taken of the number of lesions of leaf spot, early blight, and late blight, on 10 leaves picked at random from the plants in the two inner rows of each plot. The results obtained are recorded in Tables 1 to 4.

RESULTS

Leaf Spot (*Septoria lycopersici*)

In 1953 and 1955, all treatments, as compared with the check, gave significant control of leaf spot, but there was no significant difference between the various treatments. In 1954, a very severe epiphytotic of leaf spot occurred and certain differences were evident. The data

TABLE 2—COMPARISON OF THE EFFICIENCY OF VARIOUS FUNGICIDES AND FUNGICIDE COMBINATIONS FOR THE CONTROL OF EARLY BLIGHT (*Alternaria solani*) ON GENEVA JOHN BAER TOMATOES DURING 1955

Treatment	Average number of lesions of early blight per 10 leaves*
No spray except one application of DDT for the control of hornworms	16.3
COCS 55 (6 lb. in 80 gal. water)	3.8
Vancide Z-65 (2–80)[1]	11.0
Tank-mixed COCS (3 lb.) and Vancide Z-65 (1 lb.) in 80 gal. water	2.0
Vancide Z-65 (2–80)[1] for first half of schedule; COCS 55 (6–80) for second half	6.0
Tricop (6–80)[2]	12.5
Manzate (2–80)[1]	2.3
Tank-mixed Tricop (3 lb.) and Manzate (1 lb.) in 80 gal. of water	2.5
Manzate (2–80)[1] for first half of schedule; Tricop (6–80)[2] for second half	2.5
Vancide F-995W (2–80)[1]	10.8
Vancide F-956W (2–80)[1]	8.5
Vancide ME-4698 (2–80)[1] (mixture of F-995W & F-956W)	15.3
Captan (2–80)[1]	7.8
	L.S.D.'s at 5% level
	1955 7.7

* Average of 4 plots receiving each treatment

[1] 2 lb. in 80 gal. water

[2] 6 lb. in 80 gal. water

presented in Table 1 indicate that the fixed copper COCS 55, the tank mixture of COCS 55 and Vancide Z-65, Tricop, Manzate, the tank mixture of Tricop and Manzate, and the split schedule of Manzate and Tricop gave good control of leaf spot. Vancide Z-65, Vancide F-995W, the split schedule of Vancide Z-65 and COCS 55, and Zerlate gave only moderate control. Vancide F-956W gave inadequate control.

Early Blight (*Alternaria solani*)

Although inoculum of *Alternaria solani* was applied each year, early blight developed to a significant degree only in 1955, when it was generally severe throughout Ontario. In this year, COCS 55, the tank mixture of COCS 55 and Vancide Z-65, Manzate, the tank mixture of Tricop and Manzate, and the split schedule of Manzate and Tricop gave good control of early blight. The other treatments, Vancide Z-65, the split schedule of Vancide Z-65 and COCS 55, Tricop, Vancides F-995W, F-956W, and ME-4698, and Captan gave poor control (Table 2).

TABLE 3—COMPARISON OF THE EFFICIENCY OF VARIOUS FUNGICIDES AND FUNGICIDE COMBINATIONS FOR THE CONTROL OF LATE BLIGHT (*Phytophthora infestans*) ON THE FRUIT AND FOLIAGE OF GENEVA JOHN BAER TOMATOES DURING 1954 AND 1955

Treatment	Average number of lesions on 10 leaves*	Average number of blighted fruits*	
	1954	1954	1955
No spray except one application of DDT for the control of hornworms	9.8	175.5	9.6
COCS 55 (6 lb. in 80 gal. water)	0.0	0.3	0.8
Vancide Z-65 (2–80)[1]	3.0	47.5	2.4
Tank-mixed COCS 55 (3 lb.) and Vancide Z-65 (1 lb.) in 80 gal.	0.3	1.3	0.0
Vancide Z-65 (2–80)[1] for the first half of schedule; COCS 55 (6–80)[2] second half	0.0	0.5	0.8
Tricop (6–80)[2]	0.0	0.0	0.0
Manzate (2–80)[1]	0.0	0.8	0.0
Tank-mixed Tricop (3 lb.) and Manzate (1 lb.) in 80 gal.	0.0	0.5	0.0
Manzate (2–80)[1] for first half of schedule; Tricop (6–80)[2] for second half	0.0	1.0	0.0
Vancide F-995W (2–80)[1]	0.3	13.0	0.0
Vancide F-956W (2–80)[1]	0.0	9.8	0.0
Vancide ME-4698 (2–80)[1] (mixture of F-995W & F-956W)	—	—	0.0
Zerlate (2–80)[1]	0.8	20.3	—
Captan (2–80)[1]	—	—	0.0

		L.S.D.'s at 5% level	
		Fruits	Lesions
* Average of 4 plots receiving each treatment	1954	24.9	2.0
	1955	1.7	

[1] 2 lb. in 80 gal. water
[2] 6 lb. in 80 gal. water

Late Blight (Phytophthora infestans)

This disease developed in epiphytotic proportions only in 1954, although it attacked a significant number of the fruits in 1955 without spreading appreciably on the leaves. Table 3 shows that all treatments, with the exception of Vancide Z-65, gave good control of late blight on the fruit and foliage. In 1955, when the disease was not nearly so severe, all treatments gave good control. It was noted in 1954 that the combination of Vancide Z-65 and COCS 55, as a tank mixture or as a split schedule, gave a degree of control significantly better than Vancide Z-65 alone. Manzate and Tricop employed singly, or as a tank mixture, or in a split schedule, were very effective in controlling late blight.

Percentage of Diseased Fruit

The category "diseased fruit" comprises not only fruits showing symptoms of early blight and late blight, but all those with blossom-end rot and with cracks that had become colonized by fungi. With the exception of late blight, the data showing the incidence of each of these disorders are not significant by themselves. However, the figures for the total percentage of diseased fruit harvested during 1954 and 1955 show some significance (Table 4).

TABLE 4—COMPARISON OF THE EFFICIENCY OF VARIOUS FUNGICIDES AND FUNGICIDE COMBINATIONS FOR THE CONTROL OF DISEASE IN RIPENED FRUITS OF GENEVA JOHN BAER TOMATOES DURING 1954 AND 1955

Treatment	Average percentage of weight of diseased fruit harvested*	
	1954	1955
No spray except one application of DDT for the control of hornworm	73.5	27.0
COCS 55 (6 lb. in 80 gal. water)	46.8	20.7
Vancide Z-65 (2–80)[1]	60.4	18.7
Tank-mixed COCS 55 (3 lb.) and Vancide Z-65 (1 lb.) in 80 gal.	32.9	19.7
Vancide Z-65 (2–80)[1] for first half of schedule; COCS 55 (6–80)[2] for second half	43.7	21.6
Tricop (6–80)[2]	51.1	21.7
Manzate (2–80)[1]	36.9	16.5
Tank-mixed Tricop (3 lb.) and Manzate (1 lb.) in 80 gal.	43.0	21.0
Manzate (2–80)[1] for first half of schedule; Tricop (6–80)[2] for second half	47.9	20.5
Vancide F-995W (2–80)[1]	40.2	21.8
Vancide F-956W (2–80)[1]	49.0	21.3
Vancide ME-4698 (2–80)[1] (mixture of F-995W & F-956W)	—	21.0
Zerlate (2–80)[1]	40.0	—
Captan (2–80)[1]	—	18.9
	L.S.D.'s at 5% level	
	1954	12.7
	1955	4.2

* Average of 4 plots receiving each treatment

[1] 2 lb. in 80 gal. water
[2] 6 lb. in 80 gal. water

In both 1954 and 1955, all sprayed plots yielded a significantly lower percentage of diseased fruits than the check plots. In 1954, the plots sprayed with the tank mixture of COCS 55 and Vancide Z-65 yielded less diseased fruit than those sprayed with the COCS 55 or Vancide Z-65 alone, but not significantly less than those that received the split schedule of three sprays of Vancide Z-65 and 3 of COCS 55. No significant difference was noted where the Manzate and Tricop combinations were used, except that Manzate gave significantly better control than Tricop. In 1955, the total amount of diseased fruit was considerably less than in 1954 and differences were not so marked. Manzate gave better control than COCS 55, the split schedule of Vancide Z-65 and COCS 55, Vancides F-995W, F-956W, and ME-4698, and Tricop, but not better than Captan, the Manzate and Tricop combinations, the Vancide Z-65 and COCS 55 tank mixture, and Vancide Z-65 alone. However, Manzate in 1954 significantly excelled only Vancide Z-65 and Tricop.

DISCUSSION

From the results of tests conducted during three seasons in which no disease appeared consistently in epiphytotic proportions, few generalizations can be made about the efficiency of the various treatments. No information was obtained concerning their ability to control anthracnose. However, it is felt that the results indicate that there is a certain amount of specificity on the part of at least some of the fungicides. Tricop controlled late blight and leaf spot effectively, but was not as effective against early blight on the foliage as some other fungicides, particularly COCS 55 and Manzate, both of which controlled leaf spot, late blight, and early blight equally well.

Vancide Z-65, Vancide F-995W, Vancide F-956W, and Zerlate were generally somewhat less effective than the other materials. In the case of the Vancide Z-65 and COCS 55 tank mixture, it is suspected that the increased efficiency over Vancide Z-65 alone is due mainly to the action of the fixed copper.

The tank mixtures and the split schedules were generally not more effective than the components used singly. Where there was an improvement in fungicidal effectiveness, i.e. control of leaf spot by the Vancide Z-65 and COCS 55 tank mixture, or control of early blight by the Tricop and Manzate tank mixture, the increase in effectiveness attained the level of that of COCS 55 or Manzate respectively. No synergistic effect was evident except in 1954 (Table 4), when the plots sprayed with the Vancide Z-65 and COCS 55 tank mixture yielded less diseased fruit than either material used alone. This did not recur during 1955.

On the basis of the results obtained from the tests during three seasons, it may be concluded that six applications of COCS 55 or of Manzate in a normal season will control leaf spot, early blight, and late blight. Tricop seems to be satisfactory for the control of leaf spot and late blight, but in comparison with other fungicides, it is not as effective against early blight on the foliage. During the one year in which it was used, Captan

compared favourably with Manzate in controlling leaf spot and early blight, but it will need further testing during a more severe late blight year.

The usefulness of these materials for the control of anthracnose in the Ottawa area could not be determined on account of the absence of the disease in the plots during the three seasons in which the trials were conducted.

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GROWTH AND DEVELOPMENT OF SOME FIELD CROPS AS INFLUENCED BY CLIMATIC PHENOMENA AT TWO DIVERSE LATITUDES[1]

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[Received for publication February 6, 1957]

ABSTRACT

The investigation involved establishment of an experimental site at Madison, Wisconsin, latitude 43°N., and another at Beaverlodge, Alberta, 55°N., where 10 annual crops representing varieties of wheat, oats, barley peas and millet were grown for two years. Growth and phenology of the varieties were correlated with meteorological conditions at the two points. Climatic phenomena studied were insolation, air temperature, photo- and thermoperiod, and water relations. Over the growing season, insolation was approximately equal at Madison and Beaverlodge, despite the high latitude of the latter point. On the other hand, the effective heat supply at Beaverlodge was only 60 per cent of that at Madison. The photoperiods at the two locations were found to be quite different.

Under the long summer days of the more northerly latitude at Beaverlodge all crops except millet developed as well as at Madison. Millet proliferated vegetatively and did not head at Beaverlodge. The yield of seed of all crops except millet was associated with much less vegetation at the northern station. The earlier-maturing varieties did comparatively better under cool temperatures than did the later-maturing types. The results indicate that from the standpoint of seed production the plants at Beaverlodge were subjected to cooler temperatures than the comparable plants at Madison. In the phase from heading to maturity this temperature difference was less pronounced than from emergence to heading. All varieties grew taller and greater in size at Madison, but all except millet produced heavier kernels at Beaverlodge.

INTRODUCTION

The rapidity with which most cereals head and produce seed in northern environments has often been noted (1), while others, such as millet produce heads too late to ripen seed before the onset of winter[3]. The causes for these responses in plants grown at high latitudes have not been extensively examined. Before cultivated plants can be bred objectively for these regions, such studies should be made.

The amount of potentially good arable land in the Canadian Northwest has been estimated at 13,000,000 acres (5) but profitable crop production with existing varieties on much of this area is questionable. The abundance of this undeveloped land stresses the importance of this study.

Growth chambers (23) or controlled-environment greenhouses (31), where environmental factors can be controlled within comparatively narrow limits, have been used by other investigators to facilitate such studies. Experimental sites established in the field with plants and meteorological instruments in close proximity may also be used to do this. The present investigation employs the field method.

[1]Contribution from the Division of Field Husbandry, Experimental Farms Service.
[2]Agronomist.
[3]Carder, A. C. The influence of certain climatic factors on the growth and development of some crop plants. *Unpublished doctoral thesis*, Univ. of Wisconsin. 1954.

LITERATURE REVIEW

Previous field studies on the effects of climate on crops have assumed several forms. A popular approach has been the recording of a factor such as yield and describing its relation with one or more climatic factors by the use of statistical procedures (10). This method does not study the response of plants to environment throughout their growth cycle. Gregory (13) and Tincker and Jones (29) have correlated certain features of the growing crop with accompanying environmental conditions.

The microclimate of agricultural crops has been frequently studied to assess its characteristics, particularly in relation to the climate existing outside of the crops (2, 7, 27). These investigations have shown large discrepancies between temperature and humidity within a crop and those at nearby standard meteorological stations. This indicates the necessity of placing recording instruments in intimate association with the crop.

The present work resembles that of Evans (9) which dealt with the effect of latitude on the growth of timothy. However, his studies did not involve establishment of meteorological instruments at the experimental sites. True microclimatological studies attempt to determine the actual climate of the crop itself. This involves the measurement of temperature, light and humidity on the surface of plants and sometimes includes temperature within the tissues (7). Such micrometeorological measurements represent a theoretical ideal but are difficult to make and are not practical as a general procedure because of technical difficulties (8).

MATERIALS AND METHODS

Experimental sites were located at Madison, Wisconsin, 43°N., and at Beaverlodge, Alberta, 55°N., or about 800 miles apart in latitude. Care was taken to establish the sites on representative soil types and exposures for the respective areas. The study was conducted over the growing seasons of 1951 and 1952. Insolation, duration of light, mean air temperature, maximum fluctuation of air temperature, precipitation, mean air humidity, and mean hourly wind velocity were recorded or computed for each day. In addition, soil moisture measurements were taken twice a week.

Field crops studied included early-, medium-, and late-maturing varieties:

	Variety		
	Early	Medium	Late
Spring wheat	Garnet	Red Bobs	Marquis
Oats	Clinton	Beaver	Victory
Barley	Olli		Montcalm
Field peas	Chancellor		
Millet	Siberian		

The experimental areas at Madison and Beaverlodge were summer-fallowed or partially fallowed and the seed—obtained from the same source—was counted, treated with fungicide and insecticide, and seeded with fertilizer. These measures were taken to ensure similar stand and vigour of plants at each site. In 1951 seeding was done on May 8 at Madison and on May 27 at Beaverlodge; in 1952, the dates were April 21 and May 14, respectively.

Plots of each variety consisted of three rows at 1-foot spacing and 21 feet in length; the centre 16½ feet of the middle row served as the test area. Plots were quadruplicated and randomized.

Crops were studied from the aspects of phasic development and growth in size or vegetative development. Records of the following were taken:

Date of planting
Date of emergence
Date of heading (peas—date of anthesis)
Date seeds mature
Maximum height of plant, ground surface to tip of head not including awn (peas—maximum length of vine)
Dry weight of above-ground vegetative parts
Dry weight of seed
Weight per 1000 seeds.

An event was considered as having occurred when the first 50 plants in the test row showed evidence of it.

RESULTS AND DISCUSSION

Climatic Phenomena

Insolation

Extensive calculations* have shown that, from the standpoint of annual crops, Beaverlodge receives about the same amount of insolation as Madison, despite difference in latitude. Therefore, energy from solar and sky radiation cannot be of importance for the differential response of such crops at the two points. Figure 1 presents the mean insolation received over the two seasons during which the study was conducted at

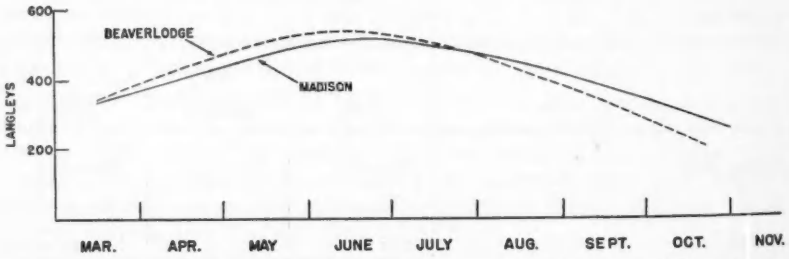

FIGURE 1. Insolation over the growing season at Madison and Beaverlodge. Average of two years, 1951 and 1952.

*Carder, A. C. The influence of certain climatic factors on the growth and development of some crop plants. *Unpublished doctoral thesis*, Univ. of Wisconsin. 1954.

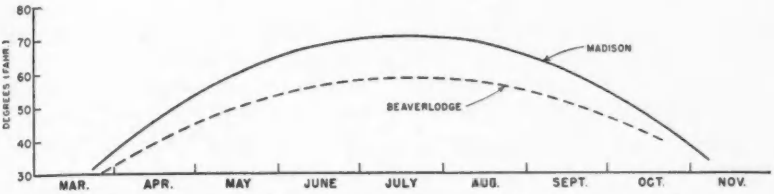

FIGURE 2a. Mean daily air temperatures for the growing season at Madison and Beaverlodge. Average of two years, 1951 and 1952.

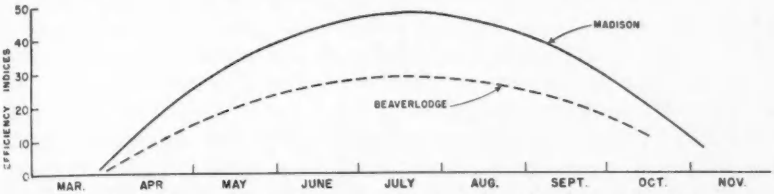

FIGURE 2b. Mean daily temperature efficiency indices for the growing season at Madison and Beaverlodge. Average of two years, 1951 and 1952.

Madison and Beaverlodge. The insolation is given in langleys (gm-cal./cm.^{2}) and represents that falling upon a horizontal plane such as the leaf surface of field crops in closed stands. The curves-of-best-fit calculated by the method of least squares show that insolation was somewhat greater at Beaverlodge up to the end of July, after which it was greater at Madison, at first slightly, then after the middle of September, considerably.

A factor contributing to this relationship is that Beaverlodge has a higher elevation, 2500 feet compared to 900 feet at Madison. More important, the atmosphere at Beaverlodge is much freer of dust and smoke particles which strongly reflect and absorb solar energy (15). These two conditions apparently compensate for the 7.2 per cent less solar radiation received at the top of the atmosphere above Beaverlodge, due to the lower declination of the sun (25), and also for any effect caused by the greater thickness of atmosphere through which the sun's rays must penetrate because of this lower declination.

Temperature

Figure 2a presents curves-of-best-fit for the average daily mean temperatures occurring over the growing seasons of 1951 and 1952 at Madison and Beaverlodge. These curves show that Beaverlodge is generally several degrees cooler than Madison and that this condition is most marked during the summer months.

The above facts at first seem anomalous since it was shown that insolation, the sole source of heat for plant growth (12), was very similar at Madison and Beaverlodge. However, while the sun is basically responsible, the warm and cold air masses that continually circulate over the surface of the earth largely determine diurnal or immediate temperatures at any one place. Beaverlodge, being nearer the pole, is more exposed to cold air masses from polar regions; also, its elevation is 1600 feet higher than Madison.

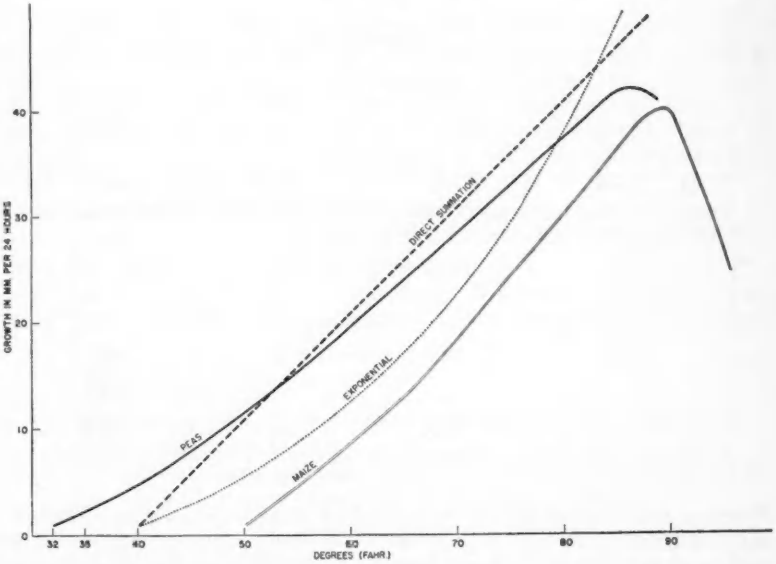

FIGURE 3. Growth rate curves for peas and maize. (*See text for explanation*).

Since the air temperature at Madison and Beaverlodge is quite different, it is necessary to determine what effect this difference has on plant growth. It has been shown (16, 17) that plant growth does not proceed in direct proportion to increase in temperature, since, within limits, for each degree rise in temperature there is somewhat more than a unit increase in growth. Leitch (17) worked out the relationship for peas, a cool-season crop, while Lehenbauer (16) studied that of maize, a warm-season crop. Growth rate curves adapted from the data of these workers are presented in Figure 3 (unbroken lines). These curves are based only on one variety of crop studied at one growth phase under one set of conditions. However, it is thought that they represent growth response to temperature more nearly than such relationships as are assumed by the exponential system based upon the van't Hoff law concept or the direct summation system (18, 20), commonly used as the basis for day-degree determinations. Growth rate curves for peas calculated on these two latter systems are shown for comparison in Figure 3 (broken lines).

The curve for peas (adapted from Leitch's data) was used to study the effect of temperature on the growth and development of crops in this investigation. Temperature efficiency indices (19) were computed from this curve for each day throughout the growing season of 1951 and 1952 at Madison and Beaverlodge. To do this for any one day the mean temperature for that day was taken and the growth rate determined from the heavy line in Figure 3. Thus, since the mean temperature for July 17, 1952, was 65°F., the temperature efficiency index for that day would be 24. This is the rate of growth (efficiency) index for that crop at that

particular temperature. Curves-of-best-fit were calculated from data obtained in this way to represent the mean temperature efficiency trend for both seasons. These are presented in Figure 2b and reveal that the difference in temperature efficiency indices between Beaverlodge and Madison was somewhat greater than the difference in mean daily air temperature (Figure 2a).

Thermoperiodicity

The phenomenon of thermoperiodicity has been described as the response of plants to rhythmic diurnal fluctuation of temperature (30). The effect of this temperature regimen is largely determined by the magnitude of the temperature and its amplitude of diurnal fluctuation. While the curves in Figure 2a show that the magnitude of the temperature at Madison and Beaverlodge are quite different, the mean monthly day-to-night fluctuations were found to be very similar, averaging, for the two years, 23.5°F. at Madison and 23.0°F. at Beaverlodge. Therefore, the thermoperiod from the standpoint of diurnal temperature fluctuation cannot be important here.

Photoperiodism

The phenomenon relating to the response of plants to the daily light period has been termed photoperiodism. It has been shown (11) that length of day is a most important factor. The function of the rate of change of length of day is not so well understood but it may be a factor, especially in high latitudes where it is pronounced (3, 11, 22). Figures 4a and 4b, comparing the daily photoperiods at Madison and Beaverlodge over the year, present both these features.

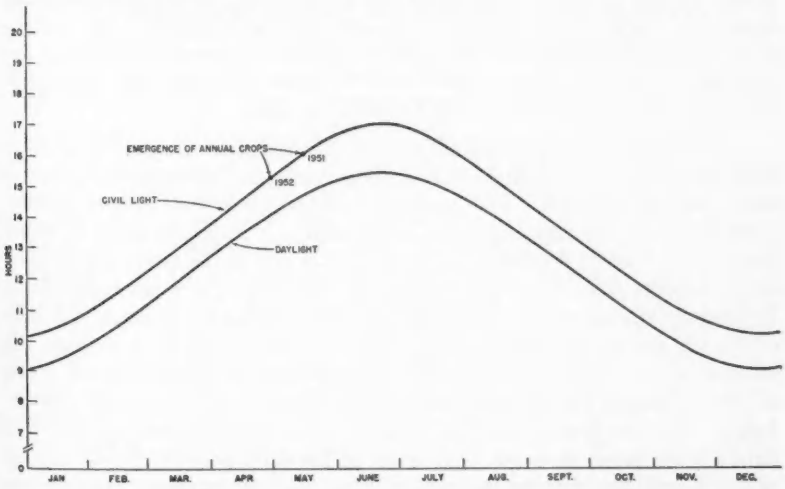

FIGURE 4a. Diurnal duration of civil light and daylight for the year at Madison.

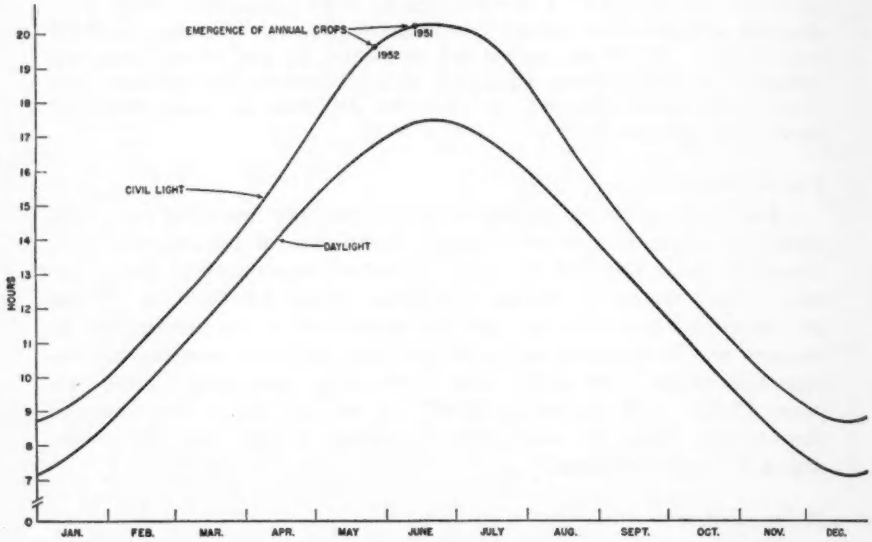

FIGURE 4b. Diurnal duration of civil light and daylight for the year at Beaverlodge.

Figures 4a and 4b also indicate the daily duration of daylight and civil light. ("Daylight" is defined as the interval between sunrise and sunset and is represented by the lower line in either figure). Photoperiodic stimulus is not curtailed with the rising or setting of the sun but functions at much lower light intensities (3, 4, 25); hence it is necessary to consider these twilight periods. The upper line in either figure is designated civil light and represents the number of hours from the beginning of morning civil twilight to the end of evening civil twilight, where civil twilight is the interval between sunrise or sunset and the time when the true position of the centre of the sun is 6° below the horizon (26).

The upper curves in Figures 4a and 4b show that during the summer half-year the daily photoperiod at Beaverlodge is considerably greater than that at Madison. The maximum difference occurs at the solstice, June 21, when the photoperiod at Beaverlodge is approximately 3¼ hours longer than that at Madison. The steeper slopes of the curve for Beaverlodge indicate that the rate of change of photoperiod is more rapid there. Because of the extension of twilight at mid-summer the greatest rapidity of change occurs after spring and before autumn equinox, a feature not evident in the daylight curve. This phenomenon is responsible for much of the difference in summer photoperiod between Madison and Beaverlodge. The emergence dates of annual crops superimposed on the civil light curves show, however, that much of the difference in rate of change of day length between the two points takes place when these crops are not likely to be affected.

Irradiance

Irradiance, illuminosity or brightness of light is closely related to degree of insolation (14, 26). Since this latter factor has been shown to be essentially the same at Madison and Beaverlodge, irradiance would not seem to be responsible for differences in plant growth and habit at the two points. Moreover, irradiance with respect to the types of crops dealt with in this study is normally so superabundant in all regions that it can hardly be considered as a differentiating factor.

Water Relations

Water use by plants was determined by the absorption block electrical resistance method (6) interpreted on a moisture stress basis (24, 28). The investigation showed that the different crops grown over the two years at Madison and Beaverlodge did not at any time suffer conditions of drought. Thus moisture differences between the two sites did not appear to be of importance.

Plant Response

The foregoing section has shown that, from the standpoint of annual plants, several meteorological phenomena were very similar at Madison and Beaverlodge, while others such as temperature and length of day were quite different. The task of this study is to relate the responses of the crop varieties to the meteorological phenomena that were different.

Certain data pertinent to the growth behaviour of the crops under test were invalidated in 1951 by an epidemic of leaf rust at Madison and by autumn frost at Beaverlodge. These data have been discarded.

TABLE 1.—AMOUNTS OF EFFECTIVE HEAT[1] ASSOCIATED WITH DIFFERENT CROP VARIETIES AS THEY PROCEEDED FROM EMERGENCE TO HEADING AND FROM EMERGENCE TO MATURITY AT MADISON AND BEAVERLODGE DURING 1951 AND 1952

Crop	Emergence to heading							Emergence to maturity		
	Madison			Beaverlodge			Madison = 100	Madison	Beaver-lodge	Madison = 100
	1951	1952	Av.	1951	1952	Av.	2-yr. av.	1952	1952	
Garnet wheat	985	1033	1009	824	723	774	76.7	2150	1901	88.4
Red Bobs wheat	1121	1041	1081	898	794	846	78.3	2219	2004	90.3
Marquis wheat	1103	1141	1122	993	1139	1066	95.0	2298	2291	99.7
Clinton oats	1136	1145	1140	708	667	688	60.4	2114	1601	75.7
Beaver oats	1165	1153	1159	800	728	764	65.9	2251	1766	78.5
Victory oats	1349	1311	1330	887	899	893	67.1	2309	2028	87.8
Olli barley	818	792	805	708	689	698	86.7	1932	1588	82.2
Montcalm barley	1136	1043	1090	1046	862	954	87.5	2097	1767	84.3
Chancellor peas[2]	942	929	936	838	793	816	87.2	2014	1981	98.4

[1]Accumulated temperature efficiency indices.
[2]Emergence to first flower.

Response to Temperature

The average accumulated temperature efficiency indices for the two years of the study for each crop from emergence to heading were computed to determine the relationships between temperature and crop growth and development. This was done by determining the number of days each crop required to pass from one developmental phase to another and then summating the temperature efficiency indices for each of the days involved. This sum was termed "effective heat". The data derived are presented in Table 1. They indicate that time from emergence to heading of all plants was associated with much less "effective heat" at

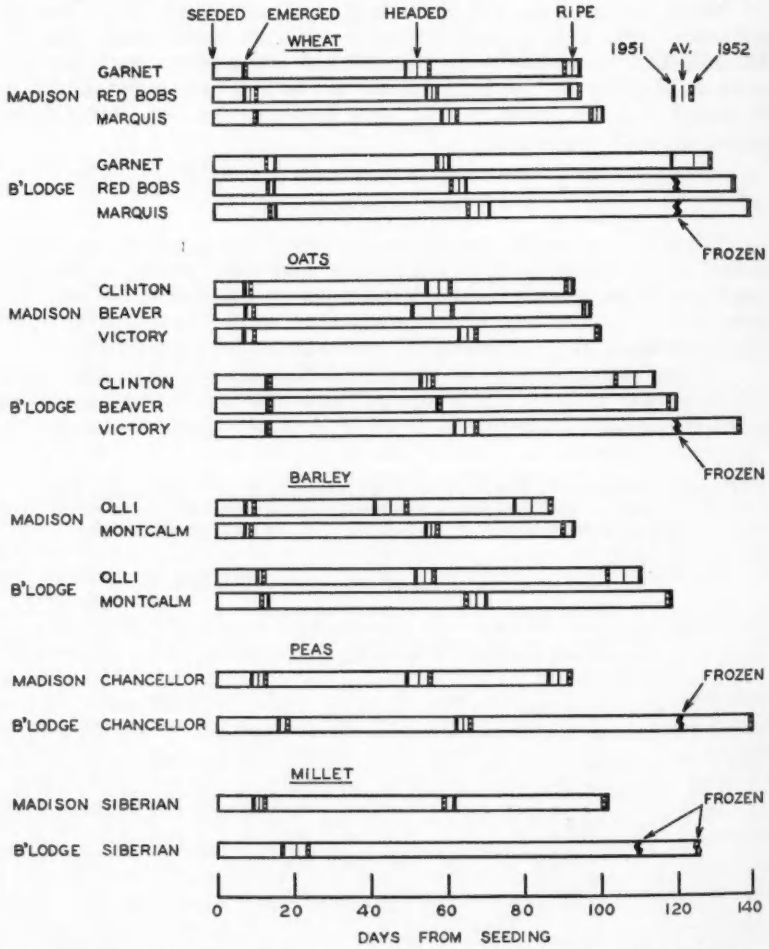

FIGURE 5. Phenology of crop varieties grown at Madison and Beaverlodge during 1951 and 1952.

Beaverlodge than at Madison. The difference is particularly marked in the case of oats, and, with all species, more marked in the case of early-maturing varieties.

Also shown in Table 1 are the amounts of "effective heat" associated with the various crops from emergence to maturity for the rust- and frost-free year of 1952. The data show that in this respect there was generally less difference between the Madison and Beaverlodge plants. Nevertheless in all instances less "effective heat" was associated with the different crops at Beaverlodge than with the corresponding varieties at Madison. The same relationship between early and late varieties held here as it did from emergence to heading, i.e., less "effective heat" attended development of early-maturing varieties. Data on the performance of millet are not listed.

Response to Photoperiod

The daily photoperiods prevailing for 21 days after emergence of the different crops averaged 16.2 hours at Madison and 20.1 hours at Beaverlodge, a difference of 3.9 hours. This 21-day period was chosen as it has been shown that the response of most varieties of annual cereals and peas to photoperiod is determined within this time (22). The response of the different crops to this phenomenon is indicated by the fact that, despite the comparatively small amount of "effective heat" available at Beaverlodge

TABLE 2.—YIELD OF GRAIN AND RATIO OF GRAIN TO STRAW OF CROP VARIETIES GROWN AT MADISON AND BEAVERLODGE IN 1952

Crop	Yield of grain[1]			Ratio of grain to straw (straw = 100)[2]	
	Madison	Beaverlodge	Beaverlodge = 100	Madison	Beaverlodge
Garnet wheat	173	241	71.8	40.0	103.9
Red Bobs wheat	107	227	47.1	27.3	86.3
Marquis wheat	120	207	58.0	27.0	73.9
Clinton oats	340	202	168.3	62.6	69.9
Beaver oats	343	260	131.9	62.3	92.5
Victory oats	303	325	93.2	48.2	105.9
Olli barley	355	224	158.5	96.7	147.4
Montcalm barley	365	262	139.3	77.8	104.0
Chancellor peas	506	208	243.3	45.0	85.6
Siberian millet[3]	317	—	—	31.9	—

[1]Gm. dry matter per rod-row.
[2]Dry matter basis.
[3]Frozen before heading at Beaverlodge.

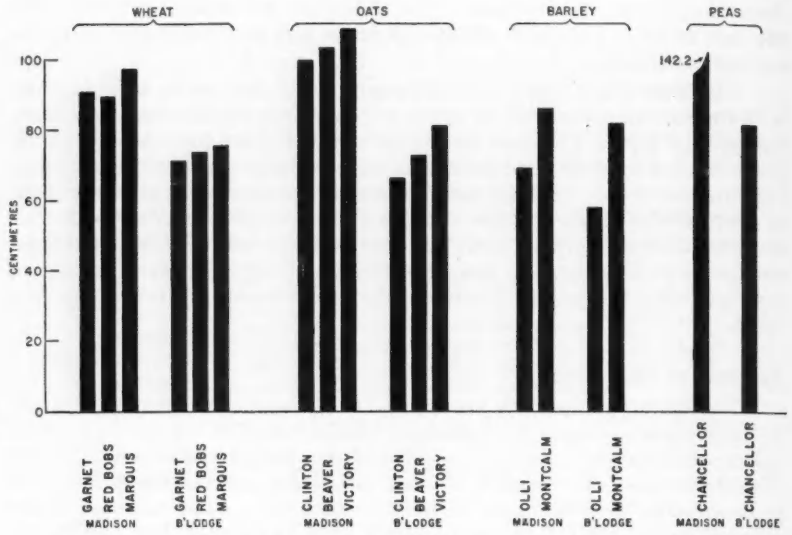

FIGURE 6a. Maximum height of crop varieties grown at Madison and Beaverlodge in 1952.

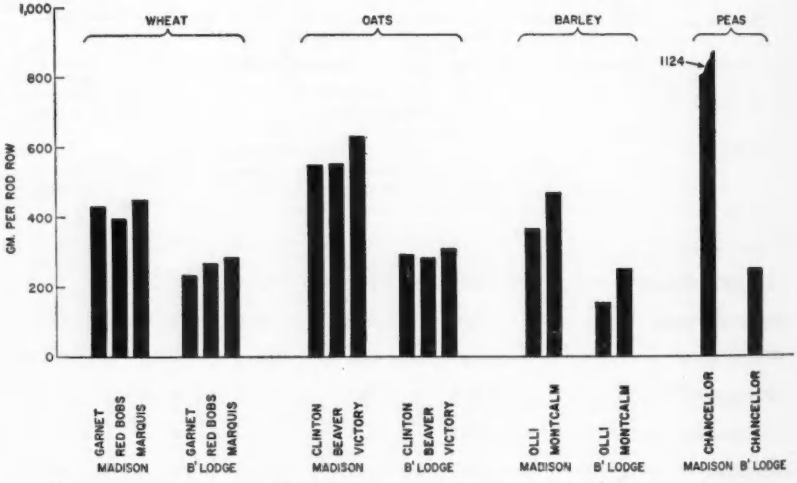

FIGURE 6b. Maximum yield of above-ground vegetative parts of crop varieties grown at Madison and Beaverlodge in 1952.

(Figure 2b), they were brought to the heading stage with about the same rapidity as at Madison (Figure 5). Oats required less time, barley and peas more, and wheat very nearly the same.

Figure 5 shows that the seed of all varieties emerged more rapidly at Madison than at Beaverlodge, although with the exception of millet

the differences were small. While in all instances emergence to heading was about the same at the two points, heading to ripening was much slower at Beaverlodge. This indicates that time of heading may be a function of one or more factors the sum of whose influence was the same at the two points, while time of ripening may be a function of one or more factors the sum of whose influence was different. What these factors are is difficult to envisage. The data suggest that to time of heading the long days at Beaverlodge compensated for lack of "effective heat". After heading this stimulus ceased and the phasic development of the crops was then dependent on temperature.

Yield and Size of Plants

Two ways to describe the size of plants are the maximum height and dry weight attained by the above-ground vegetative parts. Pertinent data obtained in the rust- and frost-free year of 1952 are presented in Figures 6a and 6b. Trends are the same in either case. All crops grew larger at Madison than at Beaverlodge. With few exceptions, the later varieties grew taller and produced more weight of vegetative matter than the earlier selections. Data for millet are not given; this crop was still developing vegetatively at Beaverlodge when destroyed by frost.

Yield of seed is a criterion for growth of reproductive parts in grain crops. Data for 1952 in Table 2 indicate that yields of the varieties of wheat were much greater at Beaverlodge, while yields of the varieties of barley and of peas were much greater at Madison. Comparative yields of the different varieties of oats varied; Clinton, an early variety, yielded over two-thirds more at Madison than it did at Beaverlodge, while the yield of Beaver was about one-third greater at Madison than at Beaverlodge. On the other hand, Victory, a late variety, yielded somewhat more at Beaverlodge. This varietal response of oats at the two points is thought to be largely due to hot weather occurring at Madison at time of anthesis; such an event damages the pollen. Early oats are more likely to escape injury inasmuch as they pass through the critical growth stage before temperatures become excessive.

Data in the last two columns of Table 2 show that the crops at Madison produced more vegetative matter than seed per unit of dry weight at maturity. On the other hand, there were several instances when those at Beaverlodge produced more weight of seed than of vegetative matter. For example, Olli barley produced almost 50 per cent more weight of seed than vegetation per unit of dry matter. The reasons for these relationships are obscure. The fact that the ratios at Madison and Beaverlodge are not the same suggests that heading and vegetative growth are controlled by different factors. Apparently once flowering has occurred the maximum amount of vegetative growth is limited. Vegetative growth, then, is a function of "growing conditions" before flowering—in this case temperature. The data further indicated that, except for oats at Beaverlodge, the earlier varieties tended to produce more seed per unit of vegetation than the later-maturing varieties.

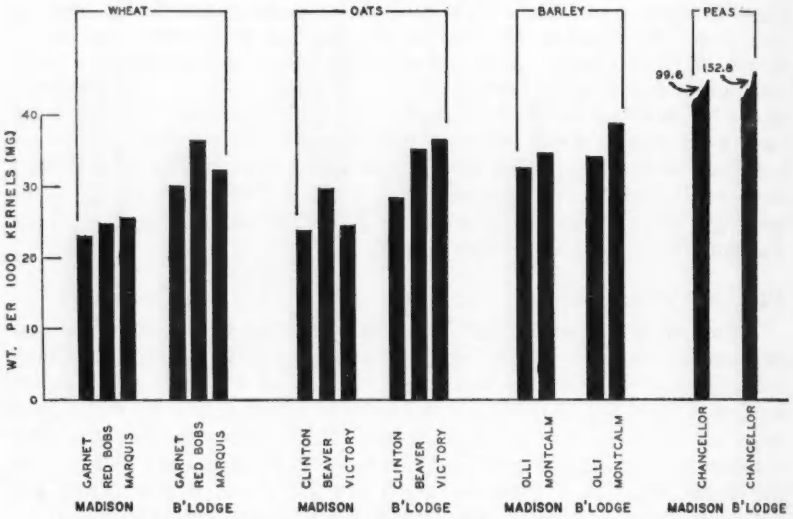

FIGURE 7. Weight of seed per 1000 kernels produced by crop varieties grown at Madison and Beaverlodge in 1952.

Figure 7, comparing kernel weight of seed produced by the various crops in 1952, indicates that every variety produced heavier kernels at Beaverlodge. Whether this was due to fewer seeds being set or the longer period between heading and ripening at Beaverlodge is difficult to determine. Data in Table 2 suggest that, except for wheat, fewer seeds were set under conditions at Beaverlodge. The later-maturing varieties generally produced heavier seed than the earlier types.

CONCLUSIONS

It was found that:

1. Temperature and length of day were largely responsible for the differential growth behaviour of the crop varieties at Madison and Beaverlodge.

2. Except for millet, less "effective heat" was associated with the maturation of all crops at Beaverlodge than at Madison. This relationship was most marked for the early-maturing varieties.

3. Millet proliferated vegetatively at Beaverlodge and though its inflorescence formed it did not break from the sheath.

4. All crops grew larger at Madison than at Beaverlodge. At both sites the later-maturing varieties generally grew taller and produced more weight of vegetative matter than the earlier selections.

5. Differences in yield of seed of the different crops between Madison and Beaverlodge were indeterminate, as were differences in yield of seed between early- and late-maturing varieties.

6. The crops at Beaverlodge produced more seed per unit of vegetative matter than those at Madison.

7. All crops except millet produced heavier kernels at Beaverlodge.

It is extremely significant that certain crop varieties yielded comparably at Madison and Beaverlodge since Beaverlodge has so much cooler summer temperatures. A much longer photoperiod at Beaverlodge is believed to be the major compensating factor. The phenology of the crops tested indicated that the effect of the photoperiod in hastening reproductive development functions before heading.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to P. O. Ripley, K. W. Hill, J. R. Hay and G. W. Robertson, of the Field Husbandry Division, Central Experimental Farm, Canada Department of Agriculture, Ottawa, Ont.; to M. J. Wright, University of Wisconsin, and to E. C. Stacey, Experimental Farm, Beaverlodge, Alta., for their painstaking review of the manuscript and helpful suggestions during its preparation.

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FACTORS IN RELATION TO TUBER QUALITY IN POTATOES.

IV. TUBER METABOLIC STAGE AND ITS INFLUENCE ON TOTAL SOLANINE[1]

by

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[Received for publication March 12, 1957]

ABSTRACT

Total solanine determinations were made on tubers of Netted Gem and Irish Cobbler potatoes that were (1) at sprouting and at fully resting metabolic stages; (2) illuminated with 15 w. and 150 w. incandescent light sources for 0 to 48 hours at 6-hour intervals; and (3) exposed to temperatures of 4° C. and 12° C. during the light treatments. Varietal differences in response were noted. Exposures longer than 6 hours made little change in solanine build-up, and the light treatments produced more effect than did the temperatures used. Sprouting tubers of Irish Cobbler showed a significant decrease in glycoalkaloid content; but under the same temperature and light conditions resting tubers of this variety showed a slight increase. Sprouting Netted Gem tubers showed little change after treatment, whereas in the dormant stage the solanine content decreased slightly under low light and increased after exposure to the 150 w. light source.

INTRODUCTION

Solanine is a physiologically active glycoalkaloid of *Solanum tuberosum* L. and certain other species of this genus. Its molecule is composed of the alkaloid solanidine combined with one molecule each of rhamnose, galactose and glucose (5). The bitter-tasting alkaloid has poisonous properties that have caused concern in certain geographical areas and seasons when the solanine content of potato tubers has been abnormally high.

Lampitt and co-workers (5) have reported that "total solanine", (solanine and free solanidine, if present) is highest in potato flowers, that dormant tubers have their greatest concentration in the peel and near the eyes, and that as tubers resume active growth solanine appears to be synthesized in large amounts. Conner (3) found that tubers exposed to ultra-violet light increased in solanine content and Zitnak (8) determined that infra-red light exposure had a very pronounced stimulatory effect upon solanine syntheiss in dormant tubers. He also found that on exposure to ultra-violet light there was a decrease in synthesis of the glycoalkaloid with decreasing exposure temperatures (8). Later work by the same worker indicated that solar irradiation of tubers immediately after harvest resulted in a rapid increase in solanine and the magnitude of this effect varied inversely with the temperature. He also found that Netted Gem tubers illuminated at low temperatures showed a marked increase in solanine whereas Irish Cobbler tubers showed no such effect under the same conditions (8, 9).

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Several workers suggest that relatively high solanine levels are associated with increased metabolic activity (5, 6, 7, 8.) Zitnak postulates that, during dormancy, synthesis of solanidine and its conversion to solanine may require a photochemical stimulus which in turn tends to be more efficient as the temperature is reduced (9). Bömer and Mattis (1), in early solanine work, show that actively sprouting tubers react to a limited degree only to environmental conditions in the matter of solanine increase or degradation. Zitnak (8) has confirmed this.

As a part of a general investigation into factors of environment that contribute to abnormal synthesis of solanine in potato tubers, trials were devised to assess the importance in this respect of the stage of tuber metabolism. Different conditions of light intensity and temperature were employed with tubers of two potato varieties at growth periods of full rest and active sprouting. The following paper records the results of this phase of work on solanine.

MATERIALS AND METHODS

Tubers of two potato varieties were used as experimental material. These were Netted Gem, a variety that has shown a pronounced ability to develop high solanine content; and Irish Cobbler, representing a varietal class that is able to maintain low levels of the compounds even under conditions normally conducive to increased synthesis. Individual samples consisted of two Netted Gem tubers weighing from 225 to 275 gm. and of a single Irish Cobbler tuber weighing from 200 to 255 gm. The replicated samples were selected at random from 100-lb. lots and were treated at the sprouting tuber stage, after 7 months' storage (May, 1955), and at the fully resting stage just after harvest (September, 1955). At the sprouting stage, Netted Gem sprouts were 1 to 3 mm. long and those of Irish Cobbler 5 to 8 cm., indicating the better storage characteristic of the first variety. Sprouts were removed prior to treatment and the tubers were washed and dried and maintained in dark storage at 12° C.

Treatments consisted of tuber exposure to incandescent light of 15 and 150 w. intensities (light source placed at 70 cm. above tubers) at 4° C. and 12° C. for 6-hour intervals from 0 to 48 hours. For each metabolic stage of each variety there were 144 samples all of which were analysed in duplicate. Temperature variation during treatment did not exceed ± 2° C.

Analytical Procedure

All sprouts that developed on active tubers during treatment were removed before the tubers were diced and macerated in a Waring Blendor for 3–4 minutes. One ml. of glacial acetic acid was added to each sample to reduce enzymatic tissue blackening and duplicate 25-gm. samples of the macerated tissue were weighed into small containers of waxed paper, polyethylene or aluminum. These were quick frozen and stored at −18° C. until they could be analysed.

The extraction and analytical procedure follows that introduced by Dabbs and Hilton in 1953 (4) and slightly modified by Zitnak (8). Essentially it involves tissue extraction for 20 hours in acidified 95% ethanol in Soxhlet apparatus; evaporation (to 2 to 5 ml.) of the alcoholic extract under reduced pressure; protein coagulation by digestion at 80° C. with sodium sulphate; filtering and washing the protein precipitate with 0.5% acetic acid; solanine precipitation with concentrated ammonia and redissolving the precipitate in 50 ml. of 0.5% acetic acid. The amount of total solanine was then estimated from the intensity of colour produced on addition of concentrated suphuric acid and 1.0% formaldehyde, using a Fisher photocolorimeter equipped with a 525-mμ filter.

Total solanine concentration was expressed in parts per million of fresh tuber weight. Tabular presentation of the data was based on means of duplicate samples, and the variation between duplicates corresponded to that reported by Dabbs and Hilton (4), where the analysis of duplicate samples showed a non-significant "$\pm$" value of 0.03 for this extraction method.

RESULTS AND DISCUSSION

Tubers in Active Stage of Metabolism

The varietal differences that were anticipated in response to treatment are evident, and are shown in Table 1. There is no clear response by the sprouting Netted Gem tubers to any condition imposed, but Irish Cobbler tubers show a marked reduction in solanine level after 6 hours' exposure, particularly under low light intensity. With one exception, all values are well below the control level and further duration of exposure does not appreciably influence the build-up or degradation of the glycoalkaloid. It is of interest that the control treatment levels of Netted Gem are "high" and those of Irish Cobbler are "normal" for total solanine content of tubers. The danger level for human consumption has been arbitrarily set at 200 p.p.m. of fresh tuber tissue.

TABLE 1.—LIGHT AND TEMPERATURE EFFECTS ON TOTAL SOLANINE LEVELS IN SPROUTING POTATO TUBERS. DATA ARE MEANS OF TWO REPLICATES, AND ARE EXPRESSED AS P.P.M. OF FRESH TISSUE.

Light intensity	Netted Gem				Irish Cobbler			
	15 w.		150 w.		15 w.		150 w.	
Temperature	4° C.	12° C.	4° C.	12° C.	4° C.	12° C.	4° C.	12° C.
Exposure hours								
0	314	314	314	314	89	89	89	89
6	196	264	477	391	36	36	59	49
12	339	209	337	166	25	33	71	34
18	442	605	504	277	54	65	38	55
24	333	287	275	493	102	63	42	61
30	376	161	317	186	47	37	62	17
36	234	306	269	331	13	62	66	72
42	455	297	362	194	31	49	31	52
48	489	408	352	280	45	47	70	81
Treatment mean (excl. "0")	358	317	352	280	44	49	55	52

TABLE 2.—LIGHT AND TEMPERATURE EFFECTS ON TOTAL SOLANINE IN RESTING POTATO TUBERS. DATA ARE MEANS OF TWO REPLICATES, AND ARE EXPRESSED AS P.P.M. OF FRESH TISSUE.

Light intensity	Netted Gem				Irish Cobbler			
	15 w.		150 w.		15 w.		150 w.	
Temperature	4° C.	12° C.	4° C.	12° C.	4° C.	12° C.	4° C.	12° C.
Exposure hours								
0	92	92	92	92	60	60	60	60
6	52	95	127	86	63	79	61	65
12	101	109	89	94	69	50	74	64
18	101	83	119	121	66	51	80	53
24	91	74	84	82	80	58	60	64
30	66	56	116	88	97	85	51	56
36	83	120	132	94	78	60	68	73
42	86	128	109	100	73	67	70	98
48	49	103	102	117	79	53	87	78
Treatment mean (excl. "0")	78	96	110	98	76	63	69	69

Tubers of Netted Gem show a mean value of 355 p.p.m. when irradiated at 4° C. and 298 p.p.m. after light exposure at 12° C. This represents an increase over the 314-p.p.m. control level at the low temperature and a slight decrease at the higher temperature. No differences were significant except the very obvious one between varieties and the decrease in total solanine in Irish Cobbler tubers after 6 hours' irradiation.

Tubers in Resting Stage

Table 2 indicates that at low temperatures, bright light tends to increase solanine in Netted Gem tubers whereas weak light decreases it. At high (12° C.) temperatures no change is evident. Data for exposure durations longer than 6 hours are highly variable with this variety; in the case of dormant Irish Cobbler tubers, the total solanine does not vary greatly after the initial slight increase following exposure for 6 hours at both temperatures and to both light intensities. There is some indication that low temperature and low light intensity combine to effect a solanine increase in dormant Irish Cobbler tubers, a result that is at variance with the effect observed on sprouting tubers of the same variety.

Varietal Response in Relation to Growth Periodicity

Table 3 summarizes the data for each of four lots of 288 duplicate analyses in such a manner as to show the influences of light, temperature and variety upon the synthesis or degradation of total solanine at the two metabolic stages in the life of the mature tubers.

The response of Netted Gem tubers, as indicated earlier, is not marked for any treatment, but statistical treatment of the data shows the differences due to metabolic stage to be highly significant. The increase in solanine in sprouting tubers at low light and temperature (14.0 per cent) is matched by a proportionate decreased level in dormant tubers under the same

TABLE 3.—TOTAL SOLANINE IN TREATED POTATO TUBERS COMPARED TO CONTROL SAMPLES. DATA ARE PER CENT INCREASE OR DECREASE FROM MEANS OF 72 SAMPLES.

Light intensity	Netted Gem				Irish Cobbler			
	15 w.		150 w.		15 w.		150 w.	
Temperature	4° C.	12° C.	4° C.	12° C.	4° C.	12° C.	4° C.	12° C.
Sprouting stage	14.0	0.9	12.1	−10.8	−50.6	−44.9	−38.2	−41.6
Resting stage	−15.2	4.3	19.6	6.5	26.7	5.0	15.0	15.0

conditions (15.2 per cent). Similarly it appears that high temperatures will offset the stimulation of solanine synthesis in tubers of this variety, while low temperatures will definitely encourage it if tubers are past their true rest period or if the light intensity is fairly high.

In Irish Cobbler variety a definite decrease in solanine levels could be proven for all treatments of sprouting tubers. Nevertheless, it must be kept in mind that the removal of a large quantity of sprouts in this variety may have affected the synthetic capacity of the tubers and thus indirectly influenced the solanine levels under the conditions of this experiment. It is quite possible that some unknown factor was translocated to the sprouts from its original locus in the tubers during the metabolic progression prior to the beginning of treatments. All treatments of dormant tubers induced increases in solanine, but these were of an insignificant order. The interaction of metabolic stage and exposure duration was found to be significant at the 5% level, which indicates that the time factor does not exert a direct influence on solanine levels in this variety.

CONCLUSIONS

In spite of the variability shown by the data, it appears that varietal response to the treatments imposed is influenced by the metabolic stage of the tubers. The initial levels of solanine in newly dug Netted Gem tubers were higher than would be expected from Zitnak's experience with this variety (8, 9). This could be explained on the basis of unseasonably cold weather prevalent at harvest time in 1955. Sprouting tubers also showed high initial solanine concentrations, but these tubers were of 1954 production, and the harvest period that year was noted for abnormally high solanine in this variety. The present trial has shown that the response at each metabolic stage depends largely upon the variety and to a lesser extent upon variation in exposures to light and temperature.

Bonner (2) suggests that alkaloids are by-products of plant metabolic processes. If this is so, the reduction in solanine brought about by exposing sprouting Irish Cobbler tubers to incandescent light, implies a reduction in the rate of metabolism. Since this is an unlikely result, it seems more probable that light, or a light-temperature relationship, is acting to inhibit certain enzyme reactions. Such inhibition may result in a lack of precursory substances necessary for solanine synthesis; or alternatively, in a dearth

of enzymes of primary or secondary association with solanine build-up. The decrease of solanine in Irish Cobbler potatoes during the sprouting stage and under the conditions imposed may on the other hand point towards the existence of a mechanism for the degradation or utilization of the glycoalkaloid in some unknown metabolic process. However, as yet, no evidence has been presented as to its possible function nor has a plausible explanation been offered to account for its presence and fluctuation in plant material.

The stimulus noted in solanine synthesis at low temperature in resting Irish Cobbler tubers was most obvious at low light intensity, and was insignificant at the higher intensity at both temperatures. A precisely opposite effect was observed with Netted Gem tubers. That a photochemical influence exists in connection with the synthesis and degradation of solanine has been shown by Zitnak (9). The present work indicates the complexity of the relationship of light with temperature and with heritable capacities of certain potato varieties to respond in a given manner to environmental conditions.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial assistance provided for this work by the Prairie Regional Committee, National Research Council of Canada.

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CHEMICAL CONTROL OF THE EUROPEAN WIREWORM *AGRIOTES OBSCURUS* (L.) IN THE LOWER FRASER VALLEY OF BRITISH COLUMBIA[1]

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[Received for publication February 13, 1957]

ABSTRACT

The wireworm *Agriotes obscurus* (L.) was controlled in silty loam at Agassiz, British Columbia, from 1953 to 1956, by insecticides incorporated into the soil. Single applications of aldrin or heptachlor at 5 lb. of toxicant per acre gave good protection to potatoes planted a month after application, and gave 100 per cent mortality of wireworms by the second or third season. Aldrin at 2.5 lb., DDT at 15 lb., and granulated heptachlor at 3 lb. did not give adequate control in the year of application but gave appreciable control in the third and fourth seasons. Ethylene dibromide at 1.6 gal. per acre did not give control.

INTRODUCTION

The European wireworm *Agriotes obscurus* (L.) was discovered near Agassiz, British Columbia, by King *et al.* (1) in 1952. Its presence there presents a new hazard to agriculture in the Fraser Valley. A survey has shown that the area affected is still relatively small, less than 800 acres; it is bounded by the Fraser River on the south and east and by heavily wooded terrain on the west and north. Although small and geographically isolated, it is a possible source of infestation to other areas relatively free from wireworms.

The soil in the infested area is silty loam. Because of the heavy annual rainfall and high water-table, soil moisture usually remains high during the summer months. Dairying is the main activity, and, except for short periods when corn may be planted for silage or canning, much of the land remains in sod for long periods. These factors, with the mild climate, provide suitable ecological conditions for this species, resulting in high larval populations.

In 1953, a long-term experiment on the control of *A. obscurus* was set up at Agassiz in a field where, in the previous year, two plantings of corn were destroyed and the stand of a fall planting of rye was reduced by 65 per cent.

MATERIALS AND METHODS

The experiment involved seven treatments plus a check, replicated three times. Each plot was 30 feet by 60 feet, or 1/24 acre. The treatments were applied on April 14, 1953, excepting the granulated heptachlor, which was applied on May 14, 1953. No treatment has been made since.

The materials used are indicated in Table 1. Dusts were applied with a small fertilizer hand cart, and emulsions with a stirrup-pump. Dusts

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TABLE 1.—STANDS OF CORN SEEDLINGS AND YIELDS OF CORN AND POTATOES IN 1953 AFTER SOIL TREATMENTS IN THE SPRING WITH VARIOUS INSECTICIDES FOR CONTROL OF *A. obscurus*, AGASSIZ, B.C.

Treatment*	Toxicant per acre	Seedlings emerged July 14	Stalks bearing ears Sept. 23	Marketable tubers %
Heptachlor dust, 2.5%	5 lb.	30	22	100
Aldrin emulsion, 23%	5 lb.	32	26	94
Aldrin dust, 2.5%	5 lb.	37	25	98
Aldrin emulsion, 23%	2.5 lb.	38	20	64
DDT dust, 5%	15 lb.	31	21	23
Heptachlor, granulated, 2.5%**	3 lb.	36	25	39
Ethylene dibromide, 85%	1.6 gal.	20	7	14
Check	Nil	10	1	4
Difference necessary for significance at 5% level		11	8	26

* Aldrin (hexachloro-hexahydro-dimethanonaphthalene) dust and emulsifiable concentrate (2 lb. toxicant per U.S. gal.) were obtained from Shell Chemical Corp., Denver, Colo.; DDT (p,p'-dichloro-diphenyltrichloroethane) from Green Valley Fertilizer and Chemical Co. Ltd., New Westminster, B.C.; ethylene dibromide (Dowfume W 85) from Dow Chemical Co., Midland, Mich.; heptachlor (heptachloro-4,7-methanotetrahydroindene) from Velsicol Corp., Chicago, Ill.

** Applied May 14. Other treatments were applied April 14.

and emulsions were applied to the surface and then worked into the soil to a depth of 6 inches by ploughing and disking. The granulated heptachlor was applied three days after planting by a fertilizer hand-cart in 18-inch bands along the rows and raked in to a depth of 2 to 3 inches. The ethylene dibromide was applied during ploughing with a home-made applicator attached to a 3-bottom plough.

The crops in these plots were as follows: 1953, Netted Gem potatoes; 1954, oats, peas, and vetch; 1955, oats, vetch, and clover; 1956, clover. On June 26, 1953, ten hills of five kernels of corn were planted in each plot when it was feared that the potato crop might fail and that damage by wireworms could not be assessed.

In 1953 the effects of the chemicals were appraised by population counts obtained from baiting and soil sifting, and by crop damage.

A corn planter was used to place ten baits, of 1 oz. of dry graham flour each, in the soil 3 to 4 inches deep, at intervals of 2 yards along two rows of each plot on May 23 and June 5; they were each examined a week later. Wireworm damage to corn was assessed by two methods: On July 14, the plants were examined to determine early damage to the seeds and seedlings; and on September 23 a count was taken of plants bearing ears to determine the effect on yield. In potatoes, where possible, 100 tubers from each plot were examined for wireworm injury. The tubers were classed as marketable, i.e., those free from wireworm injury or with superficial damage removable by normal peeling; or as unmarketable, i.e., with one or more deep penetrations, requiring extra peeling or cutting to remove the tunnels.

For soil sifting, samples were dug with a post-hole auger to a depth of 12 inches, and the soil was sifted through quarter-inch mesh screen to extract the wireworms. Eight samples per plot were taken in June and 10

per plot in August with an auger 8 inches in diameter (0.35 square feet). Because of the possible effect of the potato crop on the distribution of the wireworm population, half the samples were taken between and half within the rows.

In 1954, 1955, and 1956, when soil sifting was the only method used, ten samples per plot were taken with an auger 6.5 inches in diameter (0.23 square foot). As fodder crops were grown in these years and the plant distribution was uniform, samples were taken at random within plots.

RESULTS AND DISCUSSION

Analysis of variance shows that in 1953 only ethylene dibromide failed to give a significant reduction in damage to sweet corn (Table 1), the other treatments not being different from one another. Treatments with heptachlor dust, aldrin emulsion, and aldrin dust at 5 lb. of toxicant per acre each gave 94 or more per cent marketable potatoes, but the other treatments did not give commercial control. Potato yields based on weight could not be compared in 1953 because of differences in stand due to variation in rate of emergence and in growth of weeds early in the season. Wireworm feeding in the untreated plots was so severe that few plants survived and produced tubers. Even weed growth was noticeably curtailed. In contrast there was no appreciable reduction in plant growth in the best treated plots.

The results obtained by sifting soil from plots under potatoes in 1953 are not fully comparable with those obtained in the following years, when forage was grown. The tillage operations of the potato crop undoubtedly caused some disruption in distribution of the wireworm population. Forage crops gave more nearly uniform sampling conditions and more reliable results. Table 2 shows that the residual insecticides held the population in check over the four years. Counts obtained by sifting the soil (Figure 1) represent conservative estimates of the actual populations. Before 1953 the population was certainly well over 11 per square foot. Some of the smaller larvae were probably not taken because the wet, silty soil was difficult to sift even with quarter-inch mesh screen.

TABLE 2.—PERCENTAGE REDUCTIONS IN NUMBERS OF *A. obscurus* TAKEN IN SOIL SAMPLING FROM 1953 TO 1956 AFTER SOIL TREATMENTS IN THE SPRING OF 1953 WITH VARIOUS INSECTICIDES, AGASSIZ, B.C.

Treatment	Toxicant per acre	June 1953	Aug. 1953	Sept. 1954	Sept. 1955	Sept. 1956
Heptachlor dust, 2.5%	5 lb.	87	92	100	100	100
Aldrin emulsion, 23%	5 lb.	86	84	100	100	100
Aldrin dust, 2.5%	5 lb.	70	80	98	100	100
Aldrin emulsion, 23%	2.5 lb.	70	85	92	98	97
DDT dust, 5%	15 lb.	57	73	80	88	94
Heptachlor, granulated, 2.5%	3 lb.	25	53	62	82	89
Ethylene dibromide, 85%	1.6 gal.	14	60	56	32	3
Check*	Nil	—	—	—	—	—

* Wireworms and adults per sq. ft. in the check plots were: June 1953, 11.1; Aug. 1953, 10.5; 1954, 8.8; 1955, 7.3; 1956, 9.6.

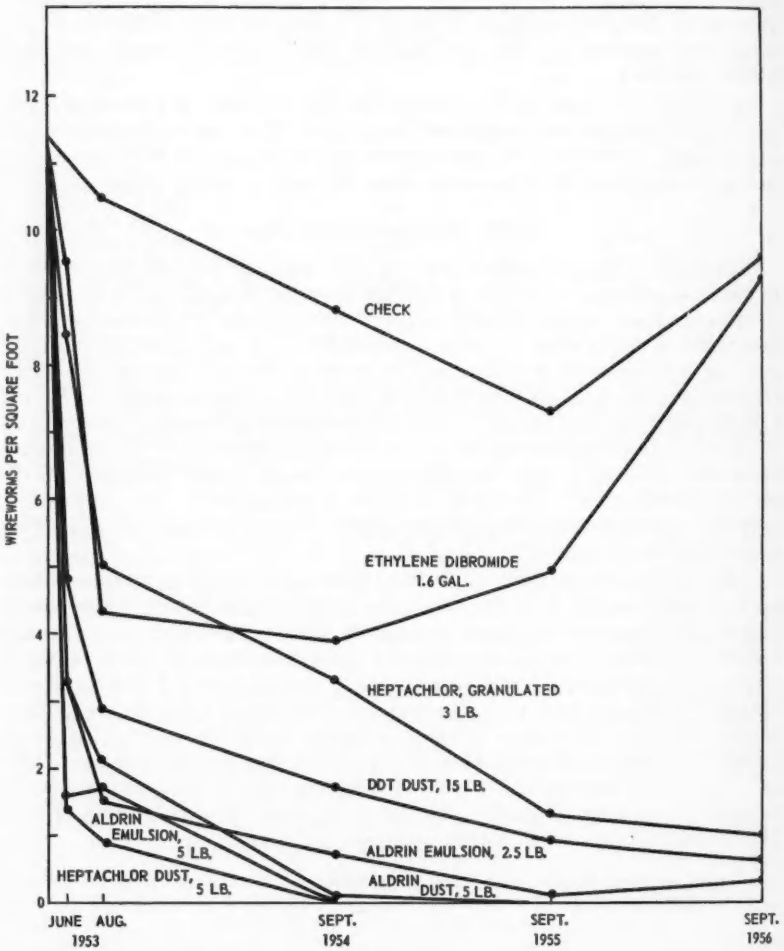

FIGURE 1. Average numbers of *A. obscurus* per sq. ft. obtained by soil sifting from 1953 to 1956 after soil treatments with various insecticides (amounts of toxicant per acre) in the spring of 1953, Agassiz, B.C.

Figure 1 shows the effectiveness of the heavier rates of heptachlor and aldrin in reducing the wireworm population from 11.1 per square foot almost to zero by the second season. It is also apparent that the normal rate of application for ethylene dibromide, used in this experiment, is too low for the wet, silty soil in the area. The same rate in light soil has given 100 per cent mortality.

TABLE 3.—AVERAGE NUMBERS OF *A. obscurus* OBTAINED IN 1953 BY BAITING AFTER SOIL TREATMENTS WITH VARIOUS INSECTICIDES IN THE SPRING, AGASSIZ, B.C.

Treatment	Toxicant per acre	Wireworms per ten baits	
		May 23–30	June 5–11
Heptachlor dust, 2.5%	5 lb.	0	0
Aldrin emulsion, 23%	5 lb.	0	1
Aldrin dust, 2.5%	5 lb.	0	0
Aldrin emulsion, 23%	2.5 lb.	2	2
DDT dust 5%	15 lb.	13	7
Heptachlor, granulated, 2.5%	3 lb.	9	6
Ethylene dibromide, 85%	1.6 gal.	27	9
Check	nil	48	41
Difference necessary for significance at 5% level		21	8

The numbers of wireworms collected by baiting (Table 3) were small in proportion to the numbers found by soil sifting. The soil moisture quickly reduced baits to sticky masses, so that they had to be removed before many wireworms were attracted. The baiting counts indicated better control than was actually obtained.

The high larval and adult populations in the check plots even in the third season and the increase in the fourth season showed that normal cultivation and farming practices, which were generally less throughout the area than those carried out in the experiment, had very little control value.

ACKNOWLEDGEMENTS

The author wishes to thank K. M. King, Officer-in-Charge, Field Crop Insect Section, Entomology Laboratory, Victoria, B.C., for assistance in planning the experiment. M. D. Noble, Vancouver, gave invaluable technical assistance.

REFERENCE

1. King, K. M., R. Glendenning, and A. T. S. Wilkinson. A wireworm (*Agriotes obscurus* (L.)). *In* Can. Insect Pest Rev. 30 : 269–270. 1952.

A CROP HARVESTER FOR FORAGE PLOTS[1]

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[Received for publication January 29, 1956]

ABSTRACT

The small crop harvester described is designed to cut yield samples from forage experimental plots. The machine, based on the principle of a flail type forage harvester, is mounted on a standard 2-plough tractor by a conventional three-point hitch and the rotor mechanism is driven from the tractor power take-off shaft. The unit cuts a swath 35 inches wide. The chopped forage material is delivered directly to an attached collection box which has a capacity for 80 lb. of green chopped material and can be unloaded from the rear. This device operates efficiently on grass or legume crops of any density with a height up to 30 inches and it chops the material into suitable lengths for sampling purposes.

INTRODUCTION

At present, most forage plots are cut with some type of garden tractor having a sickle-bar mower. Subsequent to cutting the crop is normally collected in some form of pan or bag and following this the material is chopped by another device to secure a sample for dry matter yield determinations. These numerous operations involve considerable time and labour. Accordingly, a new type of forage plot harvester has been devised which combines the operations of cutting, collecting, and chopping the crop in a single operation.

DESCRIPTION AND CONSTRUCTION

The new harvesting device for forage plots is designed as a flail-type device which cuts and chops the crop by impact and blows the cut material into a collection box. The entire machine is about 3 feet wide and 5 feet long and is mounted on a standard 2-plough tractor by a conventional three-point hitch linkage. Power to operate the rotary cutter is obtained from the power take-off shaft of the tractor. When being transported, the harvester is carried by the tractor in a raised position entirely free of the ground. When operating on plots, the harvester rests on two caster wheels which support the unit and also serve to control the height of cut. The complete unit is illustrated in Figure 1.

The rotor of the machine consists of a 3-inch heavy duty pipe to which are attached 16 flail-type cutters obtained from an Economy Model Lundell Forage Harvester. Added weights are required on the rotor for dynamic balance.

The hood over the rotor directs the cut material into the collection box. The top of the box is covered with a 1/8 × 1/8 inch metal screening to provide an outlet for the air stream created by the rotating cutters. The bottom of the box is sloped so that the chopped material can be readily removed through the rear hinged door on to a tarpaulin to be weighed.

[1] Contribution from the Field Husbandry, Soils and Agricultural Engineering Division, Experimental Farms Service.

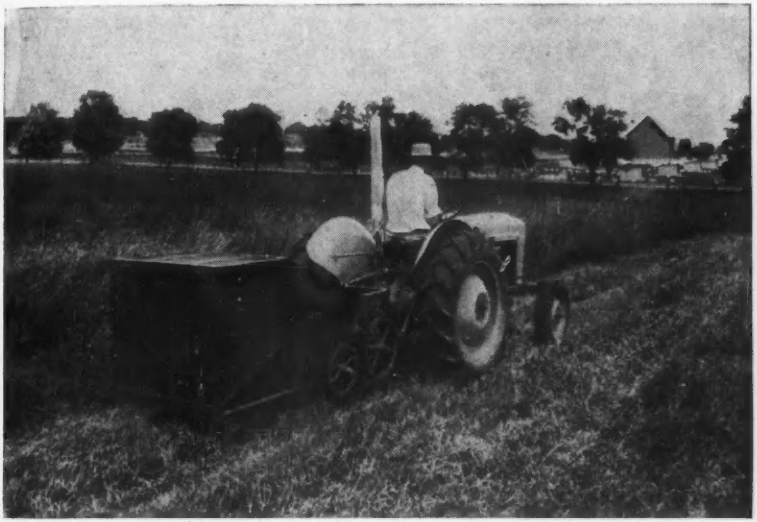

FIGURE 1. A side view of the completed plot harvester, showing the unit attached to the tractor and in operating position.

The caster wheels are set within the frame of the machine so that they will run on the cut stubble. Vertical adjustment on the wheels controls the height of cut.

The line drawing in Figure 2 shows a side view of the machine and indicates various details of construction. The cost of materials for the unit was approximately $250.00 and 100 man-hours of labour were required to construct the harvester.

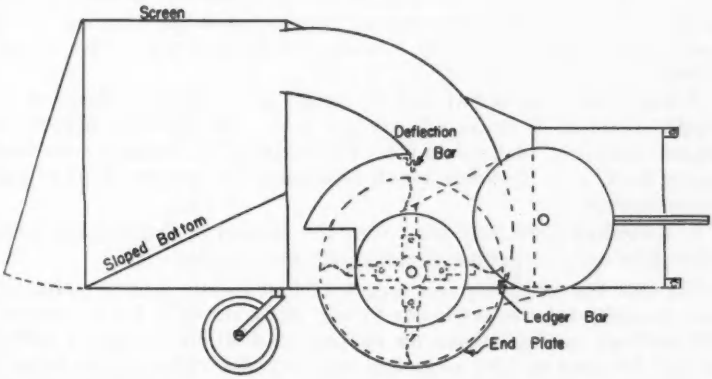

FIGURE 2. Details of the arrangement of the principal parts of the unit.

FIGURE 3. A clean cut in badly lodged alfalfa and timothy crop.

FIELD OPERATIONS

The harvester, with the tractor in first gear, is capable of handling any height and density of forage crop. Badly lodged forage crop was cut clean as shown in Figure 3. A tractor with a live power take-off makes it possible for the rotor to be brought up to cutting speed before the unit is moved into the plot for cutting, and also allows the forward motion of the unit to be stopped at the end of the plot while maintaining full rotor speed. The 2-plough tractor supplies ample power for the operation of the unit.

A minimum rotor speed of 1500 r.p.m. is required to ensure that the chopped material is delivered into the box. At this rotor speed, and a forward travel of 1½ to 2 m.p.h., the material is chopped into lengths ranging from 2 to 12 inches which is suitable for samples for dry matter determinations.

It is evident from field trials that the suction created by the rotating cutter picks up dust and chaff along with the sample.

The new harvester requires a crew of four to five men as compared to seven to eight for the sickle-bar mower method. The time required by both methods is about equal for clipping of short crops where a collection pan can be used on the sickle-bar mower. On taller crops, where the material cut by the sickle-bar must be collected and chopped, the harvester is at least twice as fast.

TABLE 1.—COMPARISONS OF METHODS OF HARVESTING FORAGE PLOTS

	Test No. 1 Timothy & Alfalfa		Test No. 2 Timothy		Test No. 3 Orchard Grass & Alfalfa		Test No. 4 Birdsfoot Trefoil & Reed Canary Clippings	
Yield lb./ac. green wt.	Harvester 16780	Sickle-bar 17330	Harvester 17330	Sickle-bar 16280*	Harvester 22600	Sickle-bar 21780	Harvester 14620	Sickle-bar 14560
Protein N × 6.25%	15.64	13.64					19.67	20.95*
Fibre %	33.25	35.24					27.01	26.79
Ash %	9.86	9.06					12.06	9.69**

* Significant at 5% level
** Significant at 1% level

The tractor used for the harvester is the only power unit required for field operations. The sickle-bar unit is often accompanied by a powered chopper and a small field tractor to move equipment to new sites.

FIELD TESTS

Tests were conducted on four crops to compare the plot harvester with a conventional sickle-bar mower for collecting samples. Each unit was used to cut swaths from 5 × 30 foot plots. The methods of harvesting were replicated three times in test No. 1 and six times in Test 2, 3, and 4 in randomized block layouts. The efficiency of collecting or harvesting the crop materials was based on yield per acre of green chopped material obtained by both methods. Any differences in the amount of trash picked up were determined by protein and crude fibre analyses. Differences in the amount of earth (dust) picked up with the samples were determined by ash analyses.

RESULTS AND DISCUSSION

According to the data in Table 1, the harvester is as efficient as the sickle-bar mower in the collection of forage plot samples. The significant difference in protein in Test No. 4 may indicate that some trash was picked up by the harvester, or may have been caused by a slightly lower height of cut. The very significant increase in ash content of the harvester samples in Test No. 4 was likely caused by dust collected with the samples.

A possible solution to the dust problem may be the use of cutters from a Standard Model Lundell Harvester. These cutters are not specifically designed to blow chopped material but may create sufficient air blast to carry the material the short distance to the collection box.

In the field, the small crop harvester operates in an efficient manner saving both time and labour. Crop yields are comparable with those obtained by other methods but samples for chemical analyses should be evaluated on a silicon-free basis.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to F. S. Nowosad and members of the Forage Division for their technical advice regarding plot technique. Thanks are extended to R. B. Carson, of the Chemistry Division, Science Service, for the chemical analysis of the samples.

SOME ASPECTS OF A RYANIA-GLYODIN SPRAY SCHEDULE IN BRITISH COLUMBIA APPLE ORCHARDS

I. ENTOMOLOGICAL, HORTICULTURAL, AND ECONOMIC ASPECTS[1]

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[Received for publication April 30, 1957]

ABSTRACT

In apple orchards at Summerland, B.C., four applications of 100 per cent ryania at 48 lb. per acre per application, with glyodin as the fungicide, gave control of light infestations of the codling moth, *Carpocapsa pomonella* (L.), similar to that from four sprays of 50 per cent DDT at 12 lb. per acre, with lime-sulphur, ferbam, and wettable sulphur. In a heavily-infested orchard, ryania was inferior to DDT. The ryania-glyodin schedule also controlled the woolly apple aphid, *Eriosoma lanigerum* (Hausm.), and the apple aphid, *Aphis pomi* DeG. It had little detrimental effect on predacious mites. Except for the apple rust mite, *Vasates schlechtendali* (Nal.), phytophagous mites were usually not so troublesome where the modified schedule was used.

Packing-house records showed that the ryania-glyodin schedule reduced the size and lowered the grade of McIntosh, Newtown, and Delicious apples, and reduced the size of Red Delicious. Grade of Red Delicious was better with the modified than with the standard schedule. The 1954 applications of the modified schedule evidently reduced the size of the 1955 crops on all varieties; most seriously affected were McIntosh with 76.2 per cent reduction and Delicious with 53.7 per cent.

INTRODUCTION

The use of DDT in apple orchards has created widespread problems in the control of insects and mites. Many entomologists consider that these problems have resulted from the destruction of parasitic and predacious insects and mites that formerly kept orchard pests below the level of commercial importance. Attempts have been made to harmonize biological and chemical control by the use of insecticides and fungicides that are relatively harmless to beneficial species. The success of any such program in British Columbia would depend upon the removal of DDT from the spray schedule and the substitution of a selective insecticide to control the codling moth, *Carpocapsa pomonella* (L.). Under the semi-arid conditions of the main fruit-growing areas of British Columbia, the codling moth is the key orchard pest; even in neglected orchards where the "biological balance" has not been upset, virtually all the fruit is damaged by this species. In contrast, the control of apple scab, *Venturia inaequalis* (Cke.) Wint., is the most important orchard problem under the more humid conditions of the Maritime Provinces and codling moth damage in non-sprayed orchards rarely reaches 20 per cent (7).

A modified spray program appeared to be promising in 1952, when workers in West Virginia found that the botanical insecticide ryania (3) gave control of the codling moth similar to that by DDT but did not destroy beneficial insects (1). In 1953, Pickett and Patterson (7) reported that ryania showed considerable promise against the codling moth in Nova

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TABLE 1.—MATERIALS, AMOUNTS, AND DATES OF APPLICATIONS OF SPRAYS, GARTRELL AND EMBREE ORCHARDS, 1955

Materials	Amount per acre per application	May 9 pre-pink	May 16 pink	June 1 calyx	June 20 1st cover	June 27 2nd cover	July 15 3rd cover	Aug. 10 4th cover
Modified schedule								
Glyodin, 34%[1]	5 qt.	×	×	×	×	×		
Ryania, 100%[2]	48 lb.				×	×	×	×
Standard schedule								
Lime-sulphur[3]	8 gal.	×	×					
Ferbam, 76%[4]	5 lb.			×	×	×		
Wettable sulphur, 92%[5]	15 lb.			×	×	×		
DDT, 50%[6]	12 lb.				×	×	×	×
Check								
Water	80 gal.	×	×	×	×	×	×	×

[1] Crag Fruit Fungicide 341, liquid; Carbide and Carbon Chemicals Ltd., Toronto, Ont.
[2] Ryanicide 100, dispersible powder; S. B. Penick & Co., New York, N.Y.
[3] Liquid, 1.28 specific gravity; Oliver Chemical Co., Penticton, B.C.
[4] Karbam Black, wettable powder; Sherwin-Williams Co. of Canada Ltd., Montreal, Que.
[5] C.I.L. Microfine Sulphur, wettable powder; Canadian Industries Ltd., Montreal, Que.
[6] Penco DDT W-50, wettable powder; Pennsylvania Salt Manufacturing Co. of Washington, Tacoma, Wash.

Scotia. The following year Patterson and MacLellan (6) concluded that ryania was an effective substitute for DDT in controlling this pest. It reduced the numbers of some other orchard insects to the point that natural control agents were adequate and, as it had little effect on the predators of mites, orchard mites did not become injurious.

Ryania was first tested in British Columbia in 1953 in an apple orchard at Okanagan Centre that had not been sprayed during the previous three years. Four sprays of Ryanexcel 96-3* [a synergized ryania powder containing 96 per cent ryania, 3 per cent *n*-propyl isome (di-*n*-propyl maleate isosafrole condensate), and 1 per cent wetting agent], applied at 15 lb. per acre to McIntosh and Winter Banana apple trees, were compared with four sprays of 50 per cent DDT wettable powder at 12 lb. per acre for codling moth control. Based on 2,500 harvested apples sampled from each non-replicated treatment, the percentages of clean fruit were: ryania, 35.9; DDT, 89.9.

In 1954, experiments were begun in British Columbia with a modified spray program. This is a report on the relative merits of this program under climatic conditions of the Okanagan Valley, particularly on the control of the codling moth and mites and on the grade and size of the fruit produced.

MATERIALS AND METHODS

In 1954 and 1955, a spray schedule of ryania and glyodin was compared with a currently recommended schedule of DDT, lime-sulphur, ferbam, and wettable sulphur in two orchards at Summerland. A group of non-sprayed trees was retained as a check plot in each orchard. The first orchard (Mr. Gartrell's) consisted of about 70 Red Delicious trees approximately 20 years old. The second (Mr. Embree's), containing about 175 trees approximately 30 years old, consisted of one McIntosh, one Winesap, two Delicious, and two Newtown blocks. The treated plots were arranged so that each contained approximately equal numbers of McIntosh, Delicious, and Newtown trees. Delicious, Newtown, and Winesap trees composed the check plot of this orchard. The plots in both orchards were not replicated.

All sprays were applied by concentrate machines applying 80 gal. of spray liquid per acre. The amounts of spray material and dates of application for 1955 are given in Table 1. The same basic spray schedules were used in 1954 with the following exceptions: (a) four fungicide sprays were applied instead of five, the "pre-pink" spray being omitted; (b) hydrated lime was included with glyodin as a defoaming agent; and (c) the check plots were not sprayed with water at each spray date. Spray dates in 1954 were May 10 ("late pink"), May 25 ("calyx"), June 4 (first cover), June 22 (second cover), July 8 (third cover), and August 17 (fourth cover).

Ryania and glyodin were tested individually in 1954 and 1955 by applying them to single plots in a third orchard (Mr. Dowd's) in the Summerland area. The entomological results in these plots were compared with those obtained from a plot sprayed only with DDT and a check plot

* S. B. Penick & Co., New York, N.Y.

treated only with water. Each plot contained 20 to 25 Delicious and Newtown apple trees about 35 years old. The amounts of each material and dates of application were the same as those for the two other orchards.

Each year, minor elements were included in the second cover spray in all plots of the three orchards, at the following rates per acre: boric acid, 2 lb.; manganese sulphate, 2; magnesium sulphate, 20; and zinc oxide, 2.

Mite populations were estimated by sampling 20 leaves from one quadrant of each of 10 trees per plot in the Gartrell and Embree orchards and from 6 to 10 trees per plot in the Dowd orchard. As the experiment was originally designed to determine the influence of the modified spray

TABLE 2.—PERCENTAGES OF HARVESTED RED DELICIOUS APPLES* INJURED BY THE CODLING MOTH IN SINGLE PLOTS, MODIFIED AND STANDARD SCHEDULES, GARTRELL ORCHARD, 1954 AND 1955

Schedule	1954			1955		
	Stung	Wormy	Clean fruit	Stung	Wormy	Clean fruit
Modified	0.2	0.1	99.7	3.5	2.7	93.8
Standard	0.1	0.0	99.9	0.5	0.2	99.3
Check	0.5	3.1	96.4	3.0	38.3	58.7

* At least 2,500 sampled per treatment.

TABLE 3.—PERCENTAGES OF HARVESTED APPLES* INJURED BY THE CODLING MOTH IN SINGLE PLOTS (1 VARIETY PER PLOT), MODIFIED AND STANDARD SCHEDULES, EMBREE ORCHARD, 1954 AND 1955

Schedule	Variety	1954			1955		
		Stung	Wormy	Clean fruit	Stung	Wormy	Clean fruit
Modified	McIntosh	0.6	0.7	98.7	2.5	4.1	93.4
	Delicious	0.1	0.0	99.9	1.8	0.5	97.7
	Newtown	0.4	0.6	99.0	2.0	0.3	97.7
Standard	McIntosh	0.0	0.0	100.0	0.3	0.2	99.5
	Delicious	0.2	0.0	99.8	0.2	0.1	99.7
	Newtown	0.2	0.1	99.7	0.0	0.1	99.9
Check	Delicious	—	—	—	3.1	43.4	53.5
	Newtown	0.6	5.9	93.5	4.9	46.0	49.0
	Winesap	0.2	5.3	94.5	3.8	25.0	71.2

* At least 2,500 sampled per variety per treatment.

schedule on mite predators and these had been practically eliminated by DDT and parathion sprays applied in previous years, the Gartrell and Embree orchards were sampled only once in 1954, on August 23 and 26 respectively. In the Dowd orchard, the influence of the individual materials on mites and their predators was studied by sampling at monthly intervals in 1954, on June 3, July 5, August 6, and September 9. During 1955, the Embree and Gartrell orchards were sampled four times: on June 10, July 11, August 2 to 4, and September 6 to 9; and the Dowd orchard on May 29, June 13, July 5, August 1, and September 6. The mites were removed from the leaves with a Henderson and McBurnie mite brushing machine, and counted under a low-power, stereoscopic microscope (4, 5).

In both years, the codling moth injury was estimated at harvest by examining 500 apples per tree from each of five trees of each variety in each plot and recording the number of apples damaged. The codling moth "stings" and worm entries in each apple were not counted. Thus an apple designated as "wormy" might have been entered by more than one larva and might have been "stung" several times. This procedure gives an index of the commercial damage. Counting all "stings" and entries in a sample of apples would provide a more accurate estimate of the codling moth population but would not give as good an indication of commercial damage.

The size of apples in the various plots was estimated by counting the apples in an orchard box as filled by the pickers. At least five boxes per tree from five to eight trees per plot were counted.

The commercial effectiveness of the spray programs was evaluated by determining the cash return to the growers. They were instructed to pick all fruit, regardless of size or insect damage. Hence, a considerable amount of cull fruit, which would normally be discarded during the picking was shipped to the packing house. In the glyodin and check plots of the Dowd orchard, where codling moth damage approached 100 per cent in 1955, the fruit was discarded in the orchard. In the packing house all fruit from each plot was kept separate and was graded, sized, and packed according to the normal procedure. The packout slips from these operations provided an unbiased commercial appraisal of the effects of the two spray schedules.

RESULTS AND DISCUSSION

Entomological Aspects

Codling Moth

Both the Gartrell and Embree orchards were well managed before the experiments were begun: the growers had reduced the codling moth damage to less than 1 per cent. The comparatively cool and wet summer of 1954 did not favour codling moth development, and during this first year of the experiment only 3.6 to 6.5 per cent of the fruit was injured in non-sprayed check trees. Under such conditions the ryania schedule gave a measure of control comparable to that of the DDT schedule (Tables 2 and 3). In 1955, infestations in non-sprayed trees varied from 29 to 51 per cent and slightly more fruit was damaged on the ryania-sprayed trees than on the DDT trees.

TABLE 4.—PERCENTAGES OF HARVESTED APPLES* INJURED BY THE CODLING MOTH IN SINGLE PLOTS (2 VARIETIES PER PLOT) AFTER 4 APPLICATIONS** OF RYANIA AND DDT, DOWD ORCHARD, 1954 AND 1955

Material	Amount per acre per application	Apple variety	1954			1955		
			Stung	Wormy	Clean fruit	Stung	Wormy	Clean fruit
Ryania, 100%	48 lb.	Delicious	3.7	4.3	92.0	19.9	46.7	33.4
		Newtown	4.7	0.8	94.5	17.5	21.8	60.7
DDT, 50%	12 lb.	Delicious	0.8	0.1	99.1	5.8	7.2	87.0
		Newtown	0.6	0.2	99.2	7.0	1.9	91.1
Check, water	80 gal.	Delicious	3.5	15.7	80.8	1.3	93.4	5.3
		Newtown	5.0	20.0	75.0	—	—	—

* At least 2,500 sampled per variety per treatment.
** No other insecticide or fungicide applied to trees in 1954 or 1955.

In 1953, over 5 per cent of the fruit was damaged by the codling moth in the Dowd orchard. During 1954 damage on non-sprayed Delicious trees averaged 19.2 per cent. Four sprays of ryania gave fair codling moth control under these conditions, but control by four sprays of DDT was better (Table 4). The following year practically the entire crop in the check trees was destroyed by the codling moth. Ryania at 48 lb. per acre failed to give satisfactory control. On the other hand, approximately 90 per cent of the fruit on the DDT plot was free of damage. It has been suggested by Clancy (1) that ryania may be useful in control of strains of the codling moth resistant to DDT. If resistant strains developed in British Columbia, the populations would probably reach a level at which ryania would be ineffective as a control agent.

Phytophagous and Predacious Mites

Generally, ryania did not favour the development of phytophagous mites to the same extent as the DDT schedule.

Ryania gave good commercial control of the clover mite, *Bryobia praetiosa* Koch (Table 5). The results indicate that ryania possesses some miticidal action, either chemical or physical, against this mite. The initial mortality after each cover spray was small but the cumulative effects of four cover sprays reduced the mites to small numbers. Glyodin, on the other hand, had no apparent effect on this mite.

The European red mite, *Metatetranychus ulmi* (Koch), the two-spotted spider mite, *Tetranychus telarius* (L.), and the yellow spider mite, *Eotetranychus carpini borealis* (Ewing), were affected similarly by ryania whether applied alone or in the schedule (Tables 5 and 6). The population trends of these mites on ryania-sprayed trees closely followed those on non-sprayed trees, but in several instances more mites developed on the ryania plots.

One of the most outstanding differences between the two schedules occurred in the control of the apple rust mite, *Vasates schlechtendali* (Nal.) (Tables 5 and 6). Neither the ryania schedule nor ryania and glyodin

TABLE 5.—AVERAGE NUMBERS PER LEAF* OF PHYTOPHAGOUS AND PREDACIOUS MITES IN SINGLE PLOTS SPRAYED 4 TIMES** WITH RYANIA, GLYODIN, AND DDT, DOWD ORCHARD, 1954 AND 1955

Material	Amount per acre per application	Clover mite		European red mite		Tetranychids[1]		Apple rust mite		*Typhlodromus* spp.		*Mediolata* sp.	
		1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955
Ryania, 100%	48 lb.	3	1	23	12	14	3	387	525	0.00	0.43	0.00	0.92
Glyodin, 39%	5 qt.	10	8	16	4	7	1	438	337	0.02	0.40	0.00	0.63
DDT, 50%	12 lb.	19	32	33	22	23	17	216	329	0.00	0.00	0.00	0.00
Check, water	80 gal.	10	11	13	8	10	1	506	384	0.01	0.81	0.11	1.40

* At least 120 leaves per treatment sampled four times in 1954 and five times in 1955.
** Five applications of glyodin applied in 1955.
[1] Including *Tetranychus telarius* (L.) and *Eotetranychus carpini borealis* (Ewing).

TABLE 6.—AVERAGE NUMBERS OF PHYTOPHAGOUS AND PREDACIOUS MITES PER LEAF* IN SINGLE PLOTS, MODIFIED AND STANDARD SCHEDULES, GARTRELL AND EMBREE ORCHARDS, 1954 AND 1955

Schedule	European red mite		Tetranychids[1]		Apple rust mite		*Typhlodromus* spp.		*Mediolata* sp.	
	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955
Gartrell orchard										
Modified	21	68	11	2	467	513	1.08	1.17	.05	.01
Standard[2]	101	201	1	39	124	11	.00	.00	.00	.00
Check	14	61	11	2	484	286	.96	1.05	.00	.00
Embree orchard										
Modified	14	73	42	2	527	631	.05	.70	.00	.02
Standard	40	45	14	31	56	49	.00	.00	.00	.00
Check	4	63	33	2	53	262	.02	1.70	.02	.03

* 200 leaves sampled per treatment, once in 1954 and four times in 1955.
[1] Including *Tetranychus telarius* (L.) and *Eotetranychus carpini borealis* (Ewing).
[2] Including a miticide applied in August of both years.

each alone gave practical control of this eriophyid. The fair to good results obtained with the DDT schedule were to be expected as it contained wettable sulphur, a material that is often recommended for the control of the apple rust mite.

Both ryania and glyodin permitted the establishment of predatory mites in the three commercial orchards. The species present in the Dowd orchard were principally *Typhlodromus occidentalis* Nesbitt, *T. fallacis* (Garman), and *Mediolata* sp. *T. occidentalis* predominated in the Embree and Gartrell orchards. On the assumption that these predators are effective biological control agents (6), the numbers present were apparently not large enough to cause any noticeable reduction in phytophagous mites, especially of the apple rust mite.

Aphids

Ryania exhibited aphicidal properties. It gave good control of the woolly apple aphid, *Eriosoma lanigerum* (Hausm.), and the apple aphid, *Aphis pomi* DeG., in the three experimental orchards. D. P. Pielou*, Entomology Laboratory, Summerland, B.C., found that one application of ryania at 4-5 lb. per 100 gal. of water killed approximately 30 per cent of both species under field conditions.

* Unpublished data.

TABLE 7.—AVERAGE NUMBERS OF HARVESTED APPLES IN AN "ORCHARD-RUN" BOX*, MODIFIED AND STANDARD SCHEDULES, GARTRELL AND EMBREE ORCHARDS, 1955

Schedule	Gartrell Orchard	Embree Orchard		
	Red Delicious	McIntosh	Delicious	Newtown
Modified	125	103	115	133
Standard	100	94	107	121
Check	114	—	206	145

* 5 boxes sampled from each of 8 trees in Gartrell orchard and from each of 5 trees per variety in Embree orchard.

TABLE 8.—PERCENTAGES OF HARVESTED APPLES OF VARIOUS SIZES AND GRADES FROM SINGLE PLOTS, MODIFIED AND STANDARD SCHEDULES, GARTRELL AND EMBREE ORCHARDS, 1954 AND 1955.

Variety	Schedule	Size			Grade		
		Large	Medium	Small and extra small	Extra fancy	Fancy	Cee
Gartrell orchard[1]							
Red Delicious	Modified	0.0	64.5	35.5	76.0	19.5	4.5
	Standard	3.5	82.1	14.4	68.0	26.2	5.8
Embree orchard[2]							
McIntosh	Modified	4.2	84.3	11.5	20.9	38.7	40.4
	Standard	10.6	81.1	8.3	37.6	37.4	25.0
Delicious	Modified	0.5	67.1	32.4	20.7	42.6	36.7
	Standard	1.1	72.6	26.3	24.8	39.0	36.2
Newtown	Modified	0.6	59.9	39.5	70.9	21.5	7.6
	Standard	4.2	60.9	34.9	89.3	7.2	3.5

[1] 1955 crop only.
[2] Average of 1954 and 1955 crops.

Horticultural Aspects

The modified schedule had a detrimental effect on the grade and quantity of fruit; packing-house records showed that apples sprayed with ryania were smaller and, with one exception, lower in grade than those sprayed with DDT (Tables 7 and 8). In addition, the average crop produced per tree in 1955 was much smaller in all plots sprayed with ryania than in those treated with DDT. Compared with 1954, the percentage crop increases or decreases in 1955 for DDT-sprayed plots were: McIntosh, +69; Delicious, +17.5; Newtown, −51.1; and Red Delicious, +17.0. Respective figures for ryania-sprayed plots were: McIntosh, −7.0; Delicious, −36.2; Newtown, −77.3; and Red Delicious, +13.8.

As a rule, trees with a light crop bear larger fruits than those with a heavy crop, but in these experiments the light-cropping, ryania-sprayed trees bore smaller apples that the heavier-cropping, DDT-sprayed trees.

Grade in red varieties is primarily an index of colour, but surface blemishes and shape of fruit are also taken into consideration. The effects of the modified spray schedule on grade were particularly noticeable in McIntosh, a variety on which it is sometimes difficult to obtain adequate colour in the Okanagan Valley. In both 1954 and 1955, picking of the ryania-sprayed McIntosh was delayed approximately one week to allow the apples to colour more fully. As indicated in Table 8, the delayed picking did not accomplish its purpose; the DDT-sprayed plot yielded 14 per cent more extra-fancy fruit in 1954 and 20 per cent more in 1955 than the ryania plot. Lack of colour on ryania-sprayed apples can be explained, in part, by accumulation of an objectionable spray deposit on the fruit, particularly on the lower branches. When the deposit was rubbed off, the apples had a mottled red and green appearance. Similar differences in down-grading were obtained on Delicious and Newtown apples. The Newtown is a green variety on which colour is not so important; it was probably down-graded because of damage caused by apple powdery mildew.

Undoubtedly the difference in size and grade of fruit was largely a reflection of tree vigour. There was every indication that variation in the vigour of the trees was induced by spray chemicals. Foliage sprayed with ryania was distinctly lighter in colour and smaller in size than that sprayed with the DDT schedule. Doubtless the inferior foliage and fruit on the ryania plots can be partially attributed to the heavy deposits of ryania, the large numbers of the apple rust mite, and (on McIntosh and Newtown) the presence of apple powdery mildew, which is not controlled by glyodin. In addition, the ryania schedule may have had a direct effect on the physiology of the trees. Garman *et al.* (2) found that glyodin advances the ripening of apples. As appropriately stated by these authors, "We may be leaf-feeding the apple tree with almost any pesticide". Undoubtedly this is the case with the DDT spray schedule, in which at least one material, ferbam, is well known to have a beneficial effect on apple trees. It is possible that the ryania schedule has an entirely opposite, or detrimental effect, in this area.

Where ryania and glyodin were applied to separate plots of Delicious, tree vigour was evidently impaired in both cases. The percentage packout of medium and large fruit on the ryania plot was 15 per cent lower than on plots sprayed with DDT alone; however, the ryania-sprayed fruit graded 7 per cent higher. Trees sprayed with glyodin alone for two successive years were distinctly less vigourous than those in the DDT-sprayed or in non-sprayed plots. A similar lack of vigour was observed in McIntosh apple trees in several commercial orchards where growers had applied glyodin for the control of apple scab. In all the glyodin-treated orchards the foliage appeared much paler than on trees in adjacent orchards sprayed with ferbam and wettable sulphur. In these commercial orchards the fruit from the glyodin-sprayed trees matured early and, at harvest time, many small, highly coloured apples had dropped.

Economic Aspects

The final appraisal of any spray program must be based on the cash returns to the grower. In British Columbia, the currently recommended program to control apple powdery mildew, apple scab, the codling moth, mites, and aphids costs a maximum of $55.00 per acre for materials annually, if malathion is included in two cover sprays for mite and aphid control. The modified spray schedule, which does not control apple powdery mildew, costs approximately $90.00 per acre, if no additional sprays are required fo mites and aphids. Both spray programs involve seven applications pe season, so that the expenditures for labour and machinery are equal.

The foregoing experiments suggest that the differences in cost of spray materials should not be over-emphasized. In future, more attention will have to be paid to the indirect effects of spray materials on the quantity and quality of harvested fruit. The point was well exemplified in the Embree orchard, where McIntosh trees sprayed with the DDT schedule grossed the grower $936.55 per acre after all packing and shipping charges had been deducted. The adjoining block sprayed with the modified schedule returned only $544.61 per acre, a difference of $391.94. Similarly, in the Gartrell orchard the returns per acre for Red Delicious were: DDT-sprayed $1,366.81, ryania-sprayed $919.70, or a difference of $447.11.

ACKNOWLEDGEMENTS

The authors are especially indebted to the managers of two packing houses, the Summerland Co-operative Growers' Association and Walters' Limited, Summerland, B.C., for grading many lots of experimentally sprayed fruit. They also wish to acknowledge the laboratory and field assistance given by Margaret J. Hall, Entomology Laboratory, Summerland, B.C., and Harry Dominique, Entomology Laboratory, Vancouver, B.C.

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SOME ASPECTS OF A RYANIA-GLYODIN SPRAY SCHEDULE IN BRITISH COLUMBIA APPLE ORCHARDS

II. EFFECT ON STORAGE QUALITY OF McINTOSH, DELICIOUS AND NEWTOWN APPLES[1]

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[Received for publication December 10, 1956]

INTRODUCTION

The quality and storage life of apples may be affected by a great variety of factors, including climate, seasonal weather conditions, cultural practices, and handling treatment. Attention has been attracted to the effects of certain spray materials on tree growth, fruit quality and finish. For example, the adverse effects of stop-drop sprays when used under certain conditions are well known and have been found to contribute to a number of storage ills.

Recently, effects upon the fruit of fungicidal and insecticidal sprays have been investigated. Palmiter and Hamilton (3) and Palmiter and Smock (4) have observed that inclusion of ferbam in the scab control program resulted in increased yield of United States No. 1 fruit. The use of sulphur during the summer resulted in reduced chlorophyll content of leaves, smaller fruit and poorer colour. In these experiments the fungicidal spray was shown to affect maturity. In one season McIntosh apples sprayed with glyodin matured 13 days before fruit treated with Tag and ferbam and over a period of five years averaged 6 days earlier. Garman *et al.* (1) suggest that foliage absorption of certain pesticide sprays may considerably affect quality, size and yield of fruit.

During 1954 and 1955 Morgan and Anderson (2) in British Columbia compared a standard program of DDT, ferbam, lime-sulphur and wettable sulphur with a modified one using ryania and glyodin. They showed that the modified schedule seriously reduced size of crop and grade of fruit. In 1955 storage experiments were conducted with McIntosh, Delicious and Newtown apples picked from trees in the Morgan and Anderson plots receiving the above spray treatments. Results of these tests are reported in this paper.

PROCEDURE

Fruit for storage tests was picked in a mature condition according to the recognized indices; e.g. firmness, ease of separation from the spur and respiration trends. Five boxes from five or more trees were thoroughly mixed to provide a representative sample from each of the modified and the standard sprayed plots of McIntosh, Delicious, Red Delicious and Newtown apples. DDT sprays are included in the standard spray program in the Okanagan Valley and for purpose of these storage tests fruit from the standard sprayed plots was considered a basis for comparison. In addition, Delicious apples were obtained from plots each of which received

[1] Contribution No. 891, Horticulture Division, Experimental Farms Service.

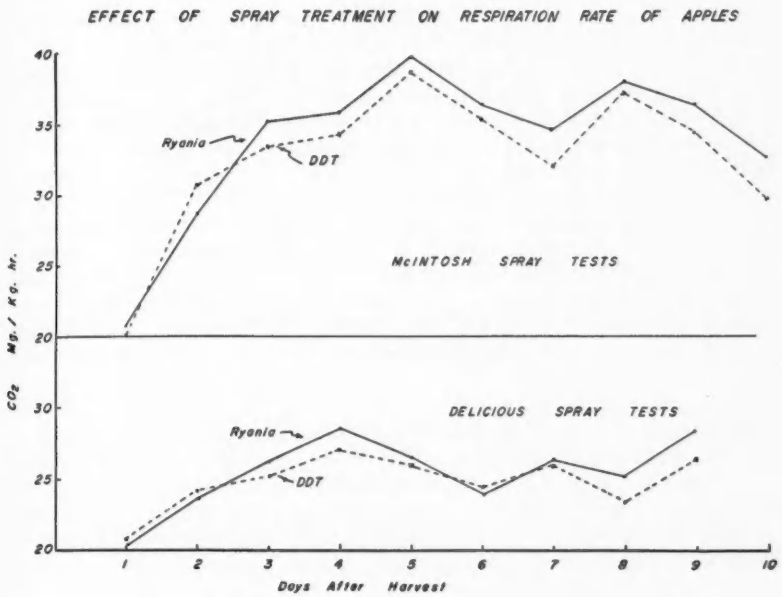

FIGURE 1. Respiration pattern at 70° F. of McIntosh and Delicious apples from plots receiving different spray treatments.

single spray treatments of ryania, DDT and glyodin. A check plot receiving only water was also included for Delicious, but not for other varieties. In this and the glyodin plot it was difficult to select samples free from codling moth injury.

Fruit was stored immediately after harvest at 31–32° F. Samples of each variety and each treatment were removed from cold storage on two different dates and placed in a 70° F. ripening-room for examination. The fruit was pressure-tested immediately upon removal from cold storage using a Ballauf tester with 7/16 inch point on 10 apples, two punches per apple, and again after 7 to 10 days at 70° F. In addition, records were made of flavour, texture, colour of skin and flesh, and disorders such as core flush and flesh browning.

At time of harvest, respiration measurements were made on samples of fruit from McIntosh and Delicious plots sprayed with ryania-glyodin and DDT-ferbam-sulphur.

Since much larger samples than represented in these tests were graded in the packing-house and dealt with in Morgan and Anderson's paper (2) no attempt was made to grade this fruit for size or colour. Only quality and condition of the fruit after various periods of storage have been evaluated.

TABLE 1.—EFFECT OF DIFFERENT SPRAY TREATMENTS ON STORAGE QUALITY OF MCINTOSH AND NEWTOWN APPLES

Treatment	Fruit condition	McIntosh					Newtown						
		Sept. 26	Jan. 9*	Jan. 19	Feb. 8*	Feb. 15	Nov. 4	Feb. 15*	Feb. 28	Mar. 16*	Mar. 27	Apr. 26*	May 7
Ryania + Glyodin	Firmness, lb.	14.93	9.36	8.67	9.65	8.50	19.39	17.32	16.40	18.32	15.44	16.26	13.66
	Flavour		F.	F.	F.	F.P.			F.G.		G.F.		F.
	Core flush			1.85		2.60			.79		1.43		2.35
	% Flesh browning								10.9		14.2		59.0
DDT + Ferbam + Sulphur	Firmness, lb.	14.52	8.82	8.68	9.52	8.48	20.15	17.24	15.42	16.52	14.34	15.47	14.54
	Flavour		F.G.	F.G.	F.G.	F.			F.G.		F.G.		F.
	Core flush			1.37		1.53			.76		1.58		1.95
	% Flesh browning								6.5		9.7		6.5
	Firmness LSD (P = .05)	.69	1.55	.38	.29	.48	.73	.54	.73	.66	.71	.42	.92
	Core flush		DDT better		DDT better			NSD		NSD		DDT better	
	Chi Square Test		P = <.001		P = <.001			P = .30–.20		P = .70–.50		P = .05–.01	

* Date removed from cold storage and placed in 70° F.

G — Good F — Fair P — Poor

Core Flush index rated 0 — 3; 3 meaning 100% fruit affected with severe core flush.

RESULTS

McIntosh

At time of harvest, fruit from the plot receiving standard spray treatment was noticeably better coloured and appeared more mature than that from the plot receiving the modified schedule. However, pressure tests at harvest and subsequently after storage, as given in Table 1, did not show the significant differences in firmness which might be expected if there was an actual difference in maturity. Furthermore, the respiration patterns of DDT and ryania-treated apples (Figure 1) were similar in respect to onset of climacteric and amplitude of the rise. From data on firmness and respiration, therefore, maturity appeared to be about the same for both lots. In all other respects ryania-sprayed fruit displayed the undesirable characteristics of immaturity; i.e. poor colour at harvest, weak flavour, greenish flesh colour, dull bronze discolouration of skin after storage and high incidence of core flush induced by storage.

Delicious

Delicious and Red Delicious (Table 2) showed little over-all difference in storage quality between standard and modified treatment. Flesh colour, generally an indicator of Delicious maturity, flavour and respiratory behaviour (Figure 1) were similar for the two treatments. Fruit from the ryania plots was slightly firmer throughout the storage period and the Delicious receiving ryania were slightly poorer in colour than fruit from DDT plots.

In the Delicious plots, ryania, DDT and glyodin were used separately in addition to a check plot where only water was applied. No consistent differences in storage quality or condition were observed between fruit from the different plots in this orchard.

Newtown

The first two examinations in February and March revealed little difference in quality between the modified and the standard sprayed samples. As shown in Table 1, there was no noticeable difference in flavour or appearance and no significant difference in core flush. Fruit samples sprayed with ryania that were tested in March and April had significantly firmer flesh than the DDT-treated samples when removed from cold storage. At the time of final examination, however, there was noticeable deterioration of the condition of fruit in the ryania lot which showed slightly more core flush and a very high incidence of flesh browning as compared with the fruit from the DDT lot.

DISCUSSION

On the basis of these tests the ryania and glyodin spray schedule appears to have adversely affected the storage quality of McIntosh and Newtown apples. The effects on storage quality of Delicious were less apparent.

DDT-treated fruit, with the exception of McIntosh, appeared to be somewhat softer than fruit from ryania treatments. A decrease in firmness of apples usually corresponds to advancing maturity and ripeness. Respi-

TABLE 2.—EFFECT OF DIFFERENT SPRAY TREATMENTS ON STORAGE QUALITY OF DELICIOUS AND RED DELICIOUS APPLES

Treatment	Firmness			Flavour	
	First removal to 70° F.		2nd removal to 70° F.	1st removal to 70° F.	2nd removal to 70° F.
	Jan. 24*	Feb. 1	Feb. 28*	Feb. 1	Mar. 2
	lb.	lb.	lb.		
Delicious					
Ryania	12.94	10.71	12.18	F.	F.
DDT	12.27	11.19	11.99	F.	F.
Glyodin	13.25	11.66	12.50	F.	F.
Check	12.57	11.06	12.02	F.	F.
LSD P = .05	.34	.46	.34		
Red Delicious					
Ryania + Glyodin	14.31	11.88	13.60	F.G.	F.
DDT + Ferbam + Sulphur	13.17	11.62	12.76	F.G.	F.
Check	13.64	11.64	12.72	F.G.	F.
LSD P = .05	.46	.31	.42		
Delicious					
Ryania + Glyodin	15.31	11.76	13.56	F.	F.
DDT + Ferbam + Sulphur	13.72	11.84	12.34	F.	F.
LSD P = .05	.38	.31	.50		

* Date removed from 32° F. storage

F — Fair

G — Good

ration tests on McIntosh and Delicious at harvest, however, failed to show any difference in the physiological condition between fruit from the two treatments. Differences in maturity were not the cause of the observed differences in storage quality of fruit.

McIntosh and Newtown apples grown in the Okanagan are subject to core flush, and Newtown may show flesh browning when the normal storage period is exceeded. In addition, the incidence and severity of these disorders may be increased by adverse conditions during the growing season. Thus, for example, considerable core flush and flesh browning may be expected during seasons which are abnormally cool and cloudy, in fruit from over-vigorous, over-stimulated trees, fruit from light crop trees or in fruit harvested in an immature condition.

Apparently the ryania and glyodin spray treatments were detrimental to normal growth and production of the trees. This is clearly indicated in reports of Morgan and Anderson (2) who observed marked reduction in crop, reduced tree vigour and poorer coloured fruit compared to trees receiving the DDT, ferbam and sulphur spray schedule. Palmiter (4) showed that glyodin sprays caused a reduction in leaf chlorophyll.

Treatments which have such marked effects on tree growth and crop may well be expected to have adverse effects upon storage quality of the fruit. Some of these effects, e.g., on colour, flesh firmness and internal disorders, are determined in this report.

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NOTE ON A SIMPLE AND EFFICIENT METHOD FOR SELECTING TETRAPLOIDS FROM A POPULATION OF RED CLOVER PLANTS OF UNKNOWN PLOIDY

One of the restricting features of plant breeding through polyploid induction is the tediousness of conventional methods of ascertaining the status of ploidy of the individual. This problem has been recognized for some time and many efforts have been made to facilitate the recognition of tetraploid individuals.

Morphological character differences have been suggested as a basis for distinction. Among the characters suggested are: unifoliate leaf size, stomatal size, leaf index, leaf thickness, length of hairs, degree of pubescence, size of stem, pollen size, incidence of pollen abortion, number of germination pores in pollen grains, size and weight of seed, and size of flowers. These characters refer specifically to red clover, and none of them is a completely reliable indication of ploidy. It has been concluded that chromosome counts is the only sure method of determining the ploidy of an individual.

However, chromosome counting is the most tedious task involved in selecting tetraploids, although much has been done to improve the techniques of preparing material for chromosome counts. Recently phase contrast microscopy has provided the most rapid way of ascertaining the ploidy of a given plant. This technique has certain limitations due to material requirements and technical ability.

The method proposed here was based on the assumption that, if red clover plants of different chromosome numbers, diploid, triploid or tetraploid, are pollinated by a known tetraploid plant, only the combination tetraploid by tetraploid will produce normal seed set. Therefore, by using a known tetraploid as the male plant, the selection of tetraploid plants from a population of unknown ploidy—such as might be obtained with colchicine treatment—should be possible.

To test this assumption, a population of 185 C_2 red clover plants was examined by this method. The size of stomata and also pollen size of these plants were checked. Chromosome counts were carried out on root tip sections of 157 of these plants—the metaphase plates of the remaining 28 plants were not satisfactory for the accurate counting of chromosomes. In order to reduce the possibility of incompatibility being the barrier to seed set, four known tetraploids which were cross-compatible with one another were used as tester males. These were designated as A, B, C and D. The procedure followed was to pollinate all unknown plants with pollen from A. If seed was produced, the amount was recorded and no further crossing was done. If no seed was produced on a specific plant, then it was pollinated with pollen from B. If this still failed to produce seed, then C was used and if necessary D was used.

If a plant produced seed in any test cross, it was classified as tetraploid; if, however, all testers failed to produce seed, then the plant was classified as non-tetraploid. One hundred and eighty-four of the plants produced plump seed (from 3 to 75 per cent) in test crosses and were classified as tetraploid. Of these, 156 were found to be tetraploid when examined

cytologically. The one plant which did not produce seed proved to be a diploid on the basis of a chromosome count. The authors believe that the data from the chromosome counts confirm the original assumption.

The advantages of this method are:

(1) It does not require the use of elaborate and expensive equipment.
(2) It does not require the services of a trained technician.
(3) It does not involve time-consuming cytological work.
(4) It provides some very useful preliminary information on seed-setting ability.

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June 3, 1957

STATEMENT OF EDITORIAL POLICY AND PRACTICE
for the
CANADIAN JOURNALS OF "ANIMAL", "PLANT", and "SOIL SCIENCE"

Types of Manuscripts Accepted

The Agricultural Institute of Canada publishes, in the "*Canadian Journal of Animal Science*", the "*Canadian Journal of Plant Science*", and the "*Canadian Journal of Soil Science*", papers reporting original research on matters relating directly to technical agriculture. Reviews of a general or purely informative nature are not usually accepted, although the Editorial Board reserves the right to invite or accept authoritative reviews from time to time.

The Editors are prepared to accept a limited number of Notes as follows:

(a) *Research Notes*, of such import as to warrant immediate release. It is expected that such Notes will be followed up by more detailed presentations or that results will be included in some subsequent, more extensive publications.

(b) *Technical Notes*, dealing with subjects such as laboratory techniques, field observations and special equipment. Such Notes would be of assistance to the research worker but would not warrant full-length publication. They would not receive the same priority of publication as would research notes.

Papers submitted must not have been published elsewhere or copyrighted. They should be as concise as is compatible with clarity. Literature reviews should be limited to only the most pertinent references. The nature of the study should be clearly stated and its scope should be defined. Results should be presented as tables, or as figures, or in the text. Presentation in more than one of these ways is definitely undesirable.

Editorial Board

The three Journals have a common Editorial Board, appointed by the National Council of the Agricultural Institute of Canada, and consisting of (a) eight members, each of whom serves for a 4-year term and two of whom retire each year; and (b) two other members, the Executive Secretary, ex officio, and a representative of the Canada Department of Agriculture. The members are selected so as to represent all fields of agriculture. The Board is responsible for making recommendations to National Council concerning editorial policy and practice for the three scientific Journals.

Representatives of Affiliated Societies are appointed by the National Council, on recommendation of the Society concerned, to assist members of the Editorial Board in the work of reviewing and editing papers submitted for publication. For the "*Canadian Journal of Plant Science*" there are three representatives, one each from the Canadian Society of

Agronomy, the Canadian Phytopathological Society, and the Canadian Society for Horticultural Science. For the "*Canadian Journal of Soil Science*", there are two representatives of the Canadian Society of Soil Science; and for the "*Canadian Journal of Animal Science*", there are two representatives of the Canadian Society of Animal Production.

Reviewing

The members of the Editorial Board and the Society representatives are responsible for (1) seeing that the manuscripts submitted for publication are properly reviewed; (2) preparing the necessary editorial comments; (3) accepting or rejecting the final submissions, bearing in mind the high standards desired. The present policy of the Board envisages the ultimate establishment of research journals which will have international recognition in their fields. To accomplish this, the standards, not only for quality of work but also for its presentation, must be high.

The Editor receives the manuscript and, in consultation with the Managing Editor, decides on the Editorial Board member or Society representative who is most likely to have some acquaintance with the subject matter of the paper, to whom the paper is then submitted. On its receipt, the person selected will normally have the paper reviewed by two other workers, independently. In those cases, however, where he feels that the subject is within his own area of competence, a review by one other worker may be sufficient. He will use the reviews, together with his own estimate of the paper, to prepare the final editorial comments which will be returned to the Editor for transmission to the author.

The reviewer is directed to assess the extent to which the paper submitted does in fact represent a piece of research carried to a well-defined stage of advance and the extent to which the conclusions are adequately supported by the experimental results. He should aim at inducing the author to condense and systematize his paper whenever necessary and to use judgement in selecting critical or representative results for presentation. He should scrutinize the paper carefully to ensure that the conclusions are sound and that the facts established by the actual investigation are not advanced in support of conclusions other than those which are legitimate. He should encourage authors to keep matters of speculation and expressions of opinion at a minimum, and to present them in short, clear statements. Every reasonable effort should be made to excise redundant, ambiguous or imprecise words, phrases or passages.

Editorial Comments

The aim of the editorial comments is to assist the author and to secure his co-operation in producing a better paper. In their preparation, the Board member or Society representative is responsible for answering the following questions:

(a) *Does this paper contain sufficient original material to justify publication in a journal devoted to original work?*

(b) *Is this paper either*

1. *inappropriate for the journal and therefore unacceptable?*
2. *acceptable as it stands?*
3. *acceptable subject to minor revision?*
4. *acceptable subject to major revision?*
5. *unacceptable?*

In those cases where the author believes that the editorial comments are not well founded, he has the privilege of asking for another independent review.